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ORIGINAL ARTICLES.

Curious Rock-Marks from Transbaikalia.

By JOHN CHALLINOR, M.A., F.G.S., University College of Wales, Aberystwyth.

IN June last (1927) Mr. K. E. Williams and I received the following letter from Mr. R. Hecker, who is in charge of the Siberian Collections at the Geological Museum, Academy of Sciences, Leningrad :—

" During my journey last year (1926) in Transbaikalia I had the chance to discover at the river Shilka, in the pile of clay-slates, changing with fine and coarse-grained sandstone, of Mesozoic age, an interesting formation which I and many others of our geologists never saw before.

" Upon the smooth surface of a plate of clay-slates, raised at the foot of a rock, I perceived numberless hooked marks one like the other, which testify a complicate movement of this plate.

" In autumn, after my return to Leningrad, I read your interesting note ' On some Curious Marks on a Rock Surface ', which bears witness of a similar discovery made, strangely, nearly at the same time.

" I think that the phenomenon you described and I met depend from the same causes and [de]note movements.

" You evidently succeeded to collect a great number of plates with marks. I beg you instantly to send me into the Geological Museum if only one plate with marks from Borth. I wish to compare it with my specimen and to exhibit them together in the Museum.

" In return I am only able to send you a photograph (twofold enlarged) which I am adding to this letter, because I possess only one single specimen from Shilka."

I have recently (September, 1927) had a further letter, acknowledging the safe arrival of the specimens sent to him and stating :—" This year a geological expedition went to the place of my discovery in Transbaikalia, but they found nothing more like it, so that I intend to publish about my discovery in one of our scientific magazines." I had told Mr. Hecker that I hoped to have the opportunity of communicating his interesting discovery to

British geologists, and commenting on it, and I wish to express my thanks to him for allowing me to do so.

The paper to which he refers was published in the GEOLOGICAL MAGAZINE in 1926 (Vol. LXIII, pp. 341–3) and his photograph shows clearly that his specimen is very similar to those we have from Borth. The figure accompanying the present paper is drawn from a representative portion of this photograph, and is an enlargement to four diameters—the actual marks are thus enlarged eight diameters in the figure. The general surface of the specimen (left blank in the figure) is seen from the photograph to be very much the same as the general surface of the Borth specimens, the marks themselves however are darker, not lighter, than their background, and they are rather smaller and more crowded than the Borth marks. There are slight differences in the detail of trace-form between the marks on different parts of the whole surface, which is about 10 square inches in area, and many of the marks, particularly the fainter ones, represent fragments of the complete trace. There are also some very faint marks which, while hooked and bent in a manner similar to the more conspicuous marks, hardly appear to conform to the general pattern. Comparing the figure with the illustrations to the previous paper (bearing in mind the various scales of these illustrations) we may note the following particular resemblances: the individual marks are bent and hooked in a similar way (though the actual form is rather more elaborate in the Russian specimen), there is the same variation in the widths (and presumably depths) of the grooves, both between individual marks and between different parts of the same mark, and the more conspicuous marks are all very nearly the same size and shape over a small area. Finally it may be noted that the formation in which the Russian specimen was discovered seems to be of much the same lithological character as the Aberystwyth Grits in which the Welsh marks occur, though the ages are very different.

Mr. Williams and I have not discovered any other "marks" in the Aberystwyth neighbourhood or elsewhere, nor have we been informed of their occurrence in other parts of Britain, and no geologist to whom we have shown our specimens has seen anything like them, though we fully expected our note would bring to light other similar cases. It is remarkable that this very distinctive rock-phenomenon at a remote spot on the Welsh coast has as yet been matched only by one small stone in the heart of Siberia. It may be mentioned that the exposure near Borth is rapidly breaking up. The question naturally arises: what is the cause of these marks which are so unlike any of the ordinary marks (organic and inorganic) occurring in such variety on rock surfaces? Their highly distinctive characters combined with their extreme rarity provides a difficult puzzle, for it is hard to imagine a special natural agency which can act so rarely or (as an alternative) an every-day agency that can on such very rare occasions (and with no obviously special conditions

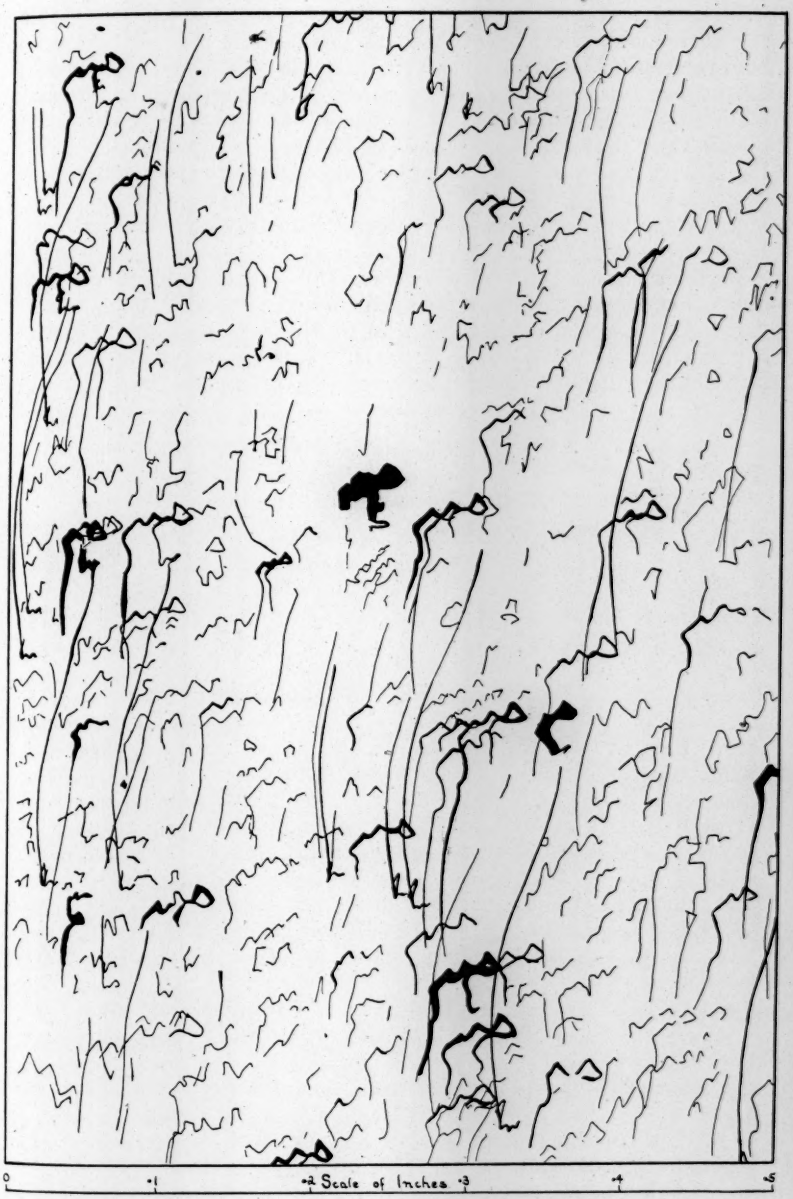

FIG. 1.—Diagram of Rock-marks from Transbaikalia.

involved) produce such peculiar effects. In the previous note it was stated that the marks were evidently due to displacement of the rock along the surface bearing them, each individual mark being a trace of the relative movement at that spot, and this movement no doubt occurred all at one time. In the letter from Russia movement is also alluded to as the cause. Professor Pugh suggests to me that they may be "fossilized natural seismograms", and Dr. Rastall, independently, has also suggested to me the possibility of a seismic origin. If that is so, is the earthquake, that was thus automatically recorded in the rocks, of comparatively recent date, or did it occur far back in geological history?

Perhaps more records of the occurrence of these curious marks, and other theories as to their origin, may be forthcoming; this further note on the subject is offered in the hope that this may be so, in addition to its main purpose, which is to communicate Mr. Hecker's discovery of the phenomenon in Transbaikalia.

The Dwyka Conglomerate.

By Professor E. H. L. Schwarz, Rhodes University College, Grahamstown, South Africa.

DR. C. G. S. SANDBERG'S article on the origin of the Dwyka Conglomerate calls for a wider publicity of the facts connected with the early establishment of the glacial origin of that deposit. The general history of the matter is given in the *Geology of South Africa*, by Drs. Hatch and Corstorphine, second ed., p. 14. The original determination was made by Dr. P. C. Sutherland in his *Geology of Natal*, Pietermaritzburg, 1868, but a number of geologists discussed it subsequently, such as C. L. Griesbach, E. J. Dunn, A. G. Bain, R. N. Rubidge, A. Moulle, G. W. Stow, R. Pinchin, A. R. Sawyer, G. A. F. Molengraaff, A. Schenck, and A. Stapff. Among the diversity of opinions expressed it was difficult to arrive at any definite conclusion at that time. In September, 1895, Dr. R. Marloth submitted to a meeting of the South African Philosophical Society a number of boulders which he thought showed glacial striations, but the evidence was not considered satisfactory by Dr. Corstorphine or myself, the only two geologists in the country.

A commission had been appointed in that year by the Cape Parliament, with Mr. C. J. Rhodes as chairman, to consider the advisability of establishing a Geological Survey, which came into existence the following year. One of my first tasks, when appointed to that survey, was to try and find criteria by which we could test the somewhat vague ideas hitherto expressed on a number of questions relating to South African geology, of which the origin of the Dwyka Conglomerate was one. On 10th September, 1896, I found at Driefontein, in the Ceres district, a perfect ice-scratched and facetted boulder firmly held in a hard, black matrix; though the refractory nature of the rock would not permit of the boulder

being removed whole, nevertheless, the fragments, when stuck together, were sufficient to allow Dr. Corstorphine to announce at the next meeting of the Philosophical Society, that the specimen was a genuine glaciated boulder.[1]

In the *Annual Report of the Geological Commission for* 1899, Cape Town, 1900, Dr. Corstorphine states: "After this (A. R. Sawyer's Report on the Prince Albert Goldfields) no additional observations were recorded as to the Dwyka Conglomerate of the Cape till 1896, when in the course of the Geological Survey Mr. Schwarz discovered undoubted ice-scratched, facetted boulders in the Ceres district, embedded in the typical hard, dark-coloured rock of the southern Karroo.[2] Since that discovery, one might think that the number of striated boulders in the conglomerate had enormously increased, for there are few places where the typical Dwyka is well exposed, which has not, without any prolonged searching, yielded good examples of ice-scratched stones. It is true that many are found with such slight traces of striations, that one would never place any weight on their evidence if unsupported, but the existence of numerous stones with unmistakable striae, throws full light on the character of the doubtful ones." Shortly after the discovery, Dr. Molengraaff arrived in South Africa, having been appointed geologist to the Transvaal Republic, and he expressed a wish to see the field evidence. I took him to the open plains east of Karroo Poort, where for miles lie scattered boulders weathered out of the till, each carrying plain evidence of glacial origin. Details of the journey were given in the *Cape Times* of 20th August, 1926. The matter was of such importance that Dr. Corstorphine thought we should see whether further evidence could not be obtained from the northern Karroo, where Dunn's map showed that the shore of the lake emerged; so Dr. Rogers and myself went to Prieska. Here we found a glacial valley, in the western side of which there are exposed some very finely preserved glaciated pavements. The till is far softer than in the south, so that under the action of weathering the covering has scaled off, revealing the hard, ice-scratched rock beneath, in the condition not very different from that in which it existed originally in Permian times. At the mouth of the valley a number of hummocks of tough amygdaloidal melaphyre project through the till, all characteristically striated on the stoss side, showing the movement of the glacier had been from the north. The occurrence was described in the *Annual Report of the Geological Commission for* 1898, Cape Town, 1900, but the photographs published in our paper on the "Orange River Ground Moraine" in the *Transactions of the South African Philosophical Society*, vol. xi, pp. 113–20, Cape Town, 1900, contributed most to the general acceptance of the view that the South African Dwyka Conglomerate was of glacial origin.

[1] *Proc. S. African Phil. Soc.*, Cape Town, 30th Sept., 1896.
[2] *First Ann. Rept. Geol. Comm.*, Cape Town, 1897, p. 28 (8vo, p. 36).

In those pioneering days it was impossible to carry out very close survey work, nevertheless we were able to establish the fact that the terrestrial conglomerate became water-sorted beyond a certain line, so that we could indicate roughly where the sub-aqueous deposition began.

In the western Karroo, on the south, the Dwyka Conglomerate rests conformably on the Carboniferous sandstone, or as it is called locally, the Witteberg Series. As one proceeds northwards, there is evidence of erosion below the Dwyka Conglomerate, and at one place the ice-sheet has ridden over the boulder clay, producing a glacial pavement. The further north one goes, the greater the erosion becomes, till successively the Witteberg, Bokkeveld and Table Mountain Series disappear, leaving the Dwyka to rest on the Malmesbury, and still further north, on the fundamental gneiss of Namaqualand.

The early geologists of the Eastern Province, Dr. W. G. Atherstone, Dr. R. N. Rubidge, R. Pinchin and A. G. Bain, were to a certain extent misled by the section north of Port Elizabeth. The high ridge of hills, the Zuurberg, are made of Witteberg sandstone, dipping south, and thus bringing down the Dwyka Conglomerate. Along the southern margin is a fault, cutting off the glacial conglomerate, and in the plane of the fault rises a sheet of basalt with two well-defined agglomerate necks. The whole forms a trap for the unwary, for anyone with a tendency to postulate a volcanic origin for the Dwyka Conglomerate, would here see apparently the material actually issuing from a volcanic fissure.

A Rare *Euryocrinus* from the Carboniferous Limestone of Coplow Knoll, Clitheroe.

By James Wright.

IN September, 1926, accompanied by my friend, Mr. James Begg, of Glasgow, I spent a few days in the Clitheroe district, being attracted thereto by a perusal of that excellent paper by Dr. Parkinson on this region (*Q.J.G.S.*, vol. lxxxii, 1926, pp. 188-249). The paper itself, with its interesting details, really fanned into flame a smouldering desire to examine the district further, since over twenty-five years ago I had read in *Our Common British Fossils*, by the late Dr. Taylor—a fascinating book to a young geologist—the statement that in the neighbourhood of Clitheroe. whole beds are composed of crinoid heads. Being in Lancashire shortly afterwards, I one day went to Clitheroe and spent a few hours in Salt Hill Quarry, but owing to ignorance of the localities and lack of experience in crinoid collecting, I was grievously disappointed so far as these fossils were concerned. When Mr. Begg and I visited the district in 1926 I recognized the landmarks and saw at once

that if I had gone further east to Bellman Quarry I should probably have been amply rewarded. On the results of our 1926 visit Mr. Begg and I were well pleased. We explored most of the knolls and quarries of the district and spent a considerable time, especially at Bellman and Coplow Quarries, where we collected a large number of well-preserved crinoids.

On cleaning and mounting my specimens in the winter of 1926, several questions cropped up, such as, how far do the Clitheroe crinoids differ from those found in Scotland ? How far do they differ or agree with the crinoids from the more bedded types of the English Carboniferous Limestone ? and, are any of these crinoids characteristic of certain beds in the knoll series ? Questions such as these appear impossible to answer satisfactorily at the present time. The first question was, however, quite a natural one, since the dominant forms at Clitheroe belong to the genera *Actinocrinus*, *Amphoracrinus* and *Gilbertsocrinus*, which so far as our knowledge goes have never been recognized in Scotland. Then as regards the third question : at Coplow in the course of collecting I had come across many loose shale blocks among the tip heaps at the back of powder house which were remarkably rich in crinoid calices, and I made an effort to fix the position of the bed to which these blocks belonged in the sequence of the quarry. In this I was successful, but did not have time to investigate the matter further. The cleaning and examination of the Coplow specimens, however, showed that the group of crinoids from this knoll appeared to differ considerably as a facies from the Bellman group, and raised a desire for a further exploration of the Coplow shale bed. Accordingly, in the autumn of 1927, I revisited Clitheroe and spent several days in Coplow Quarry.

On this occasion I did not spend much time at Bellman, since good specimens are now somewhat difficult to find. As showing, however, the great abundance of certain parts of the limestone in crinoid heads at this locality, I may mention that at a point near the top of the low cliff on the south side of the quarry where the crinoidal limestones are seen in full display, I found a patch of rotten crinoid limestone. This measured about 18 inches or so by 18 inches and about the same in depth, and from this material I dug out over forty crinoid heads. Most of these, however, were of little use, since they were in an ochrey and decomposed condition. An interesting find here was a fragment of a large crinoid root. Above the crinoid bed comes on the limestones which have yielded many specimens of Blastoids. (I am indebted for this last piece of information to Mr. George Davies, of Duck Street, Clitheroe, who has worked in Bellman for many years and has a good collection of the fossils from this quarry. He pointed out the Blastoid bed high up on the quarry face and from the screes at the foot of the limestone cliff I picked up three specimens of Blastoids.)

In the Coplow Knoll there are several shale beds interspersed with the limestones and it would be exceedingly interesting to examine

them in detail. Time, of course, would be required for this, and on the occasion of my visit, beyond a somewhat cursory inspection of other horizons, I confined attention mainly to the shale bed already mentioned. This bed occupies a position in the quarry sequence about 140 feet above the highly inclined dark limestones (here about 20 to 30 feet thick) which form the north face or wall of the quarry and which are probably about the base of the knoll limestones near their junction with the lower bedded (Chatburn) limestones so well exposed in the Horrocksford Quarry (*Q.J.G.S.*, vol. lxxxii, p. 198). The bed is pale green in colour, varies a good deal in thickness, and its fossils consist almost wholly of crinoid remains, dismembered stems, ossicles and plates, but with a considerable number of well-preserved calices. Occasionally also a flattened and dismembered echinoid may be noticed. In this bed I was fortunate to find a specimen of the rare Flexible crinoid, *Euryocrinus*, and since a large part of the arm structure is preserved—features not hitherto described for the British species—I think the occurrence interesting enough to place on record. The shale bed in question cuts right across the present quarry floor, and is only seen to advantage on the east and west sides of the quarry, where the knoll limestones are being left unworked. In the quarry itself operations are now being carried on at the south side on a lower level than the present quarry floor and in the course of a year or two it is highly probable this bed will again be cut through. One of the objects of this paper is to call attention to this so that geologists who are interested in crinoid remains may keep a look-out for this material which will then be accessible and will then be thrown out on the quarry heaps. As noted by Dr. Parkinson (loc. cit., p. 200), the quarrymen stated that one of the shale beds was particularly rich in crinoid remains when worked some years ago and this is no doubt the bed referred to. At the time of my visit in 1927 a portion of the bed was easily accessible on the west side of the quarry, and it was at this point to which I gave most attention, several square yards of the surface of the shale here to a depth of about a foot being easily worked. As mentioned, the bed is remarkably rich in crinoid calices, the most characteristic being a species of *Actinocrinus* resembling the species described by de Koninck as *A. stellaris*, (*Reser. sur Les Crinoides du Terr. Carbonifère de la Belgique*, p. 136, pl. iii, figs. 3, 4). Several large and finely preserved specimens were obtained here. Along with this species is another one probably belonging to the same genus, one probably belonging to *Amphoracrinus*, one if not two species of *Gilbertsocrinus*, several species of *Platycrinus*, and cups belonging to a species of *Poteriocrinus* closely akin to *P. conicus*, Phillips. Along with these I also found a few cups of a *Cyathocrinus*, the species of which I have not yet been able to identify. There is a fault here where both limestone and shales are slickensided and near the crushed material I found the specimen of *Euryocrinus*. This is the only crinoid which I found with the

arms nearly intact and it no doubt owes its preservation in this state to the peculiar construction of the calyx characteristic of the Flexibilia group. During the whole time I spent at Clitheroe, including an examination of Bellman and the other knolls such as Twiston, etc., I never saw a crinoid with the arms attached to the cup unless one at Coplow, where on a detached block of limestone I observed a complete crinoid, evidently a *Poteriocrinus*, with stem attached and long arms imbedded in the matrix of the block. It was only clearly seen when the rock was wet, and was impossible to extract from the limestone. The arms of this crinoid were very long and reminded me of a species which occurs in Fife, the cup of which is not unlike *P. conicus*. Here, it may be interesting to note

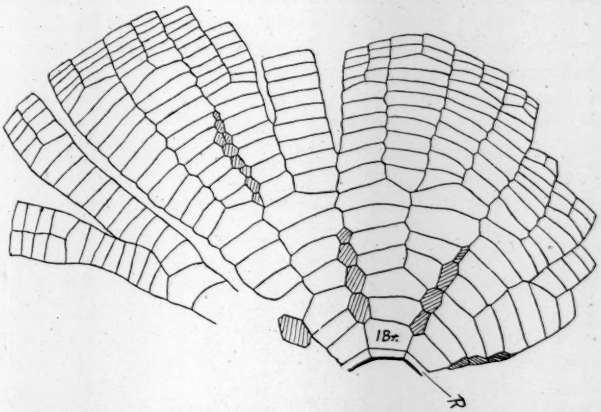

FIG. 1. — *Euryocrinus rofei* Bather & Gregory, Coplow Knoll, Clitheroe. Author's Collection, No. 1543. Interbrachial plates shaded. Nat. Size. View of one side of the specimen.

that in the Leeds Museum there are one or two specimens of *Actinocrinus* with the stems and arms attached. They are labelled *A. tesselatus* from Frome, Somerset, but I saw nothing like this state of preservation at Clitheroe.

DESCRIPTION OF THE SPECIMEN.

There can be little doubt, I think, that our specimen belongs to the rare genus *Euryocrinus* with which it agrees in essential characters, i.e. " Interbrachials few, usually limited to a single series. Primibrachs three. Arms dichotomous, abutting " (*The Crinoidea Flexibilia*, Smithsonian Institution, Washington, 1920, p. 314). The only difficulty I have is that the base is somewhat obscure, being so much cross fractured that I cannot be certain about the location of the posterior basal plate. Fig. 1 gives a good idea of the appearance of the specimen. On the right it is fairly rotund, but on the left it is somewhat flattened and for this reason, in a side view, we see more of the plates of the rays in this region than we

otherwise would had the crinoid retained its natural contour. The rounder half on the right measures 46 mm. in height, i.e. from the base to the extremities of the arms shown (IVB^2 and ^{4}), and the greatest width of the specimen is 85·7 mm. In *The Crinoidea Flexibilia*, pp. 317, 319, pl. xl, figs. 4, 5, 7, 8, Dr. Springer describes three species of *Euryocrinus* from England, all from the Yorkshire and Lancashire districts, viz. *E. concavus* Phillips, *E. rofei* Bather and Gregory, and *E. granulosus* Phillips, all the specimens of which are in the British Museum. The last-named species need not detain us and the question is, does our specimen belong to either of the first two ? If it does, to which ? In the published figures of *E. concavus* and *E. rofei* very little of the rays is shown, the highest plates preserved being the IIB^2. In *E. concavus*, the *iBr* are very narrow, in *E. rofei* they are fairly wide and conspicuous, much more like our specimen. In our Fig. 1 it will be observed that two only of the interbrachial series are completely preserved. On the left

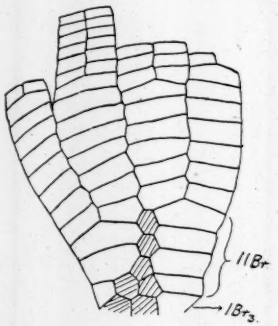

FIG. 2.—*Euryocrinus rofei* Bather & Gregory. Same specimen as Fig. 1, viewed from the other side. Interbrachial plates shaded.

of specimen one large *iBr* is in place, but the other plates of the series are not seen. Here also it may be remarked there is a gap shown in the figure just to the right of the single *iBr* which is caused by the distortion of the specimen. In the ray immediately above the gap the four *IIB* are shown and this is the correct number. On the extreme right of the specimen are seen indications of the range of interbrachials which should occupy this position, but the specimen is broken away near this point. Here then are two sets of *iBr* about which we cannot be certain, but the evidence rather points to the two ranges being in single series. Turning to the back of the specimen, Fig. 2, we find a portion of the remaining rays. The deciphering of the plates of this portion gave considerable trouble, but I think the figure gives a true picture of what may be detected. The *iBr* series here is not a complete range, but for a certain part of its course it is clear that there was a double series of plates and that the interbrachials extended up to the IIB^4.

Turning now to the figure of *E. rofei* (*Crin. Flex.*, pl. xl, fig. 7*b*), we find a double range of *iBr* in the right anterior inter-radius which possibly extended well up as in our specimen. Taking this as a clue, I have tried to fix the position of the posterior anal in our specimen, but owing to the network of cross fractures already alluded to, I cannot be sure that I have seen it. Consequently, it is not possible to fix the position of the double range of *iBr* in our specimen.

Dr. Springer says that the plates of *E. rofei* are smooth with sinuous sutures and show no sign of imbrication in contrast to *E. concavus* which has plates with tendency to imbrication. The suture lines of the plates in our specimen are not specially sinuous, although they incline that way, and there is no sign of imbrication, so that in this respect it agrees with *E. rofei*. The width of the base is, however, narrower, than *E. rofei*, which in the type-specimen is given as 14 mm. In *E. concavus* the base is narrow, being given as 10 mm. for a width of 30 mm. at the *IAx*. In our specimen the base measures 10·5 mm. with an estimated width at *IAx* of 25 mm.

An interesting feature of our specimen is the series of *iBr* which are shown on the left of Fig. 1 occupying a position high up in the middle of the ray and extending upwards from the top of *IIAx* and dividing the *IIIBr*. Altogether there are nine small plates shown here in single series, excepting one, which is a double plate. Interbrachial plates occurring high up in the rays are features sometimes seen in other species of Flexibilia, e.g. *Metichthyocrinus clarkensis* (*Crin. Flex.*, pl. xxxix, fig. 9*b*), and the top one of which, according to Dr. Springer, probably indicates the upper limit of the calyx.

Unfortunately in our specimen the tips of the arms are broken away, the longest portions being shown on the left of Fig. 1. Indications point to the fact that this is a fairly mature specimen and the distal parts of the arms no doubt gradually tapered away to a point as in *Amphicrinus scoticus*, etc. It will be observed that while the primibrachs and secundibrachs remain constant in number, i.e. in threes and fours, the tertibrachs are extremely variable, ranging from four plates on the right of specimen to eleven on the left.

The published figures of *Euryocrinus concavus* and *E. rofei* are based only on four specimens, not a great number when we consider the variations that may occur in a specialized form like this. It is to be hoped that ere long more complete specimens of this interesting crinoid may turn up so that we shall be enlightened on the precise relationships of the interbrachial plates of the two species and the variation of the arms, etc.

Taking all the facts into consideration, although our specimen differs in some details from the type of *E. rofei*, it has more affinities with that species than with *E. concavus*, and until more information is forthcoming from other specimens I am referring it to the former species and labelling it as such in my collection.

General Notes.

To a Scottish observer the distinguishing feature about the Clitheroe crinoids is the great abundance of such genera as *Actinocrinus*, *Amphoracrinus*, and perhaps in a lesser degree *Gilbertsocrinus*. These genera appear to have been at their zenith about the time of the Clitheroe knolls and to have died out at or about the close of the English Carboniferous Limestone period. This agrees with their distribution in America where they reached their acme in the Burlington Limestones and became extinct before the close of the Keokuk, horizons which are correlated with the Mountain Limestone of England (Wachsmuth and Springer, *North American Crinoidea Camerata*, pp. 233, 552, 585). In Scotland we have no record of these genera (see *Trans. Edin. Geol. Soc.*, vol. xi, p. 298, 1925 ; *Trans. Geol. Soc. Glas.*, vol. xvi, 1917–18, p. 365).

In the Scottish rocks the species of *Platycrinus*, so far as is known, probably only number three. In the Clitheroe knolls and elsewhere in the Carboniferous Limestone of England, they must far exceed this total. Further, the species in the Scottish limestones are distinguished by a low, somewhat flat, tegmen. In England many of the forms have high elevated tegmens, with prominent anal tubes. On the other hand we have in Scotland such species as *Poteriocrinus conicus*, *P. crassus*, and *P. plicatus*, which, so far as the preservation of the specimens shows, are indistinguishable from the English forms.

In the Clitheroe knolls there are apparently no *Eupachycrinus*, *Zeacrinus*, *Ulocrinus*, *Woodocrinus*, *Hydreionocrinus* or *Onychocrinus*, genera which are common in the Scottish beds. These forms, or some of them such as *Woodocrinus*, *Hydreionocrinus*, and perhaps *Zeacrinus*, are more characteristic of the Yoredale limestones in Swaledale. *Eupachycrinus calyx* MacCoy and *Ulocrinus* (*Poteriocrinus*) *nuciformis* MacCoy are recorded from the limestones of Derbyshire (*Brit. Palaeo. Foss.*, pl. 3*d*, figs. 1 and 4, p. 117).

How far the Clitheroe crinoid fauna agrees with that of the Settle district, or with that of Derbyshire or the Bristol area, etc., I am not yet in a position to say. In the Yorkshire Museum at York there are many specimens from Settle, a large number of which appear to belong to *Actinocrinus* or allied genus, all having a general resemblance to those that occur at Clitheroe and probably many of them are common to both districts. At Settle, however, occurs the rare *Sycocrinus*, originally found by the Austins and described by Dr. Bather (*Ann. Mag. Nat. Hist.*, ser. viii, vol. xiii, February, 1914, p. 245), but the precise locality of which is not stated. The species referred to this genus do not seem to have been recorded from Clitheroe.

Specifically, I find it very difficult to determine my Clitheroe specimens, since in the works I have been able to consult there seems to be considerable confusion in the nomenclature of the published species. One feels a desire to see the type-specimens instead of

figures only, since some of the latter are not very clear. The following is only a small proportion of the list of specimens in my collection :—

Coplow Shale Bed.

Actinocrinus stellaris de Kon.
,, cf. *costus* MacCoy.
,, cf. *olla* MacCoy.
,, spp.
Amphoracrinus sp.
Gilbertsocrinus calcaratus Phillips.
,, sp.
Platycrinus gigas Phillips.
,, cf. *rugosus* Miller.
,, spp.
Poteriocrinus conicus Phillips.
,, *crassus* Miller.
,, (cup with columnals).
Cyathocrinus cf. *planus* Miller.
,, sp.
Euryocrinus rofei Bather and Gregory.

Bellman Quarry.

Amphoracrinus Gilbertsoni, Miller.
,, *atlas* MacCoy.
,, sp.
Poteriocrinus plicatus Austin.
Platycrinus spp.

Twiston.

Actinocrinus tesselatus Phillips.
Platycrinus sp.

Although it is not possible at the present time to make a satisfactory comparison between the Bellman and Coplow faunas I think it will be found that there are distinctive characters in the two facies when all the crinoids which have been collected from these localities in days gone by have been fully studied and named. There must be many specimens in the British Museum and other institutions in the country besides those in private collections to throw some light on the subject, i.e. if they are properly localized. For example, two of the most noticeable and common forms at Bellman belong to species of *Amphoracrinus*, one of which resembles the figure of *A. atlas* MacCoy (*Brit. Palaeo. Foss.*, pl. 3*d*, fig. 5, p. 120), the specimen of which is said to come from Bolland. The other is probably *A. gilbertsoni* (*Geol. Yorkshire*, pt. ii, pl. iv, fig. 19). So far as my collecting goes, these Bellman species do not occur at Coplow, the predominating forms there being species of *Actinocrinus*. If they do occur they must be very rare, whereas at Bellman they

are, or were, exceedingly abundant. The same remarks apply to some of the species of *Platycrinus* (or allied genus).

At Coplow we now have an undoubted record of the Flexible crinoid *Euryocrinus*. This genus has not with certainty been found in Scotland (*Trans. Edin. Geol. Soc.*, vol. xi, p. 275, 1925). A species *E. tennesseensis* has been described by Dr. Springer from the Burlington-Keokuk horizons in America (*Crin. Flex.*, pl. xl, figs. 6 *a–c*, p. 318), and this again agrees with the distribution of the genus in England. In the Scottish beds, however, its relatives are found in the abundant *Amphicrinus* and the less common *Artichthyocrinus*, highly specialized forms and in Fife only found on one horizon (GEOL. MAG., Vol. LX, 1923, 481). The distribution of our British crinoids is a fascinating and sometimes perplexing subject, but our knowledge of it is as yet very scanty. It has not been advanced in the past by the fact that collectors have in most cases been content to state the name of a town or a district, sometimes a county, for their specimens, so that workers nowadays are left to guess the precise horizon. Phillips, for instance, gives "Bolland" as the locality for his specimens of *Euryocrinus concavus*. This may mean a wide area on the borders of Lancashire and Yorkshire. Then the locality of *E. rofei* is given as Clitheroe. This may mean any of the knolls near the town. It is even conceivable that all the specimens of *E. concavus* and *E. rofei* came from Coplow and perhaps from the bed from which the *Euryocrinus* now recorded was obtained.

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The Geology of the Northern part of the Lickey Hills, near Birmingham.

By Professor W. S. Boulton, D.Sc., F.G.S.

THE complex structure of the Lickey Hills, 7 miles south of Birmingham, has attracted the attention of geologists since the early part of last century, and interpretations of some details of their geology have been almost as numerous as the observers. The hills form part of the district recently remapped on the 6-inch scale by the Geological Survey.[1]

Extensive road widening and trench cutting for sewers carried out in the area in 1923–4 has revealed new and important information, which has already been published in part.[2]

During 1925 a deep trench was dug from the main Bristol Road at Rubery, southward along Leach Green Lane, past Leach Heath, and then westward down the cross-road called Eachway Lane. A close watch was kept on the excavation from day to day for some months, and the facts recorded. As the trench traverses a critical part of the Lickeys and the facts observed seem to have an important bearing on the structure of the district, they are set forth below, and embodied in the geological map (Fig. 1); and in the light of other observations referred to above and recently published, the general structure and history of the northern part of the Lickey range is here briefly discussed.

Summary Description of Trench Section.

Starting from Bristol Road and passing southwards along Leach Green Lane, the trench and manholes, from 10 to 12 feet deep, exposed quartzite rubble embedded in red, yellow, and lilac-blue clay for a distance of 190 yards. In part of the section (150 to 162 yards from Bristol Road) the rock fragments were almost entirely Llandovery Sandstone. For the next 155 yards the trench cut solid well-bedded quartzite, with a coarse granular texture and abundant felspar fragments. Near the cottage in the triangle of roads at the top of Whetty Lane the quartzite is overlain unconformably by the Rubery (Llandovery) Sandstone, dipping south at 20°, the dip of the underlying quartzite being 10° to the south-east. The sandstone is much stained with hematite and manganese, and contains large round pebbles of quartzite near the base, resting upon an irregular surface of bedded quartzite. At a point 60 yards further to the south-east and opposite a cottage, the Coal Measure clays rest unconformably on the Llandovery Sandstone. The clay exposed to

[1] "The Geology of the Country around Birmingham": *Mem. Geol. Surv.*, 1925. "The Geology of the Southern Part of the South Staffordshire Coalfield": *Mem. Geol. Surv.*, 1927.

[2] W. S. Boulton, L. J. Wills, and others, "New Exposures in the Rubery-Longbridge-Rednal District, south of Birmingham": *Proc. Birm. Nat. Hist. and Phil. Soc.*, vol. xv, pt. iii.

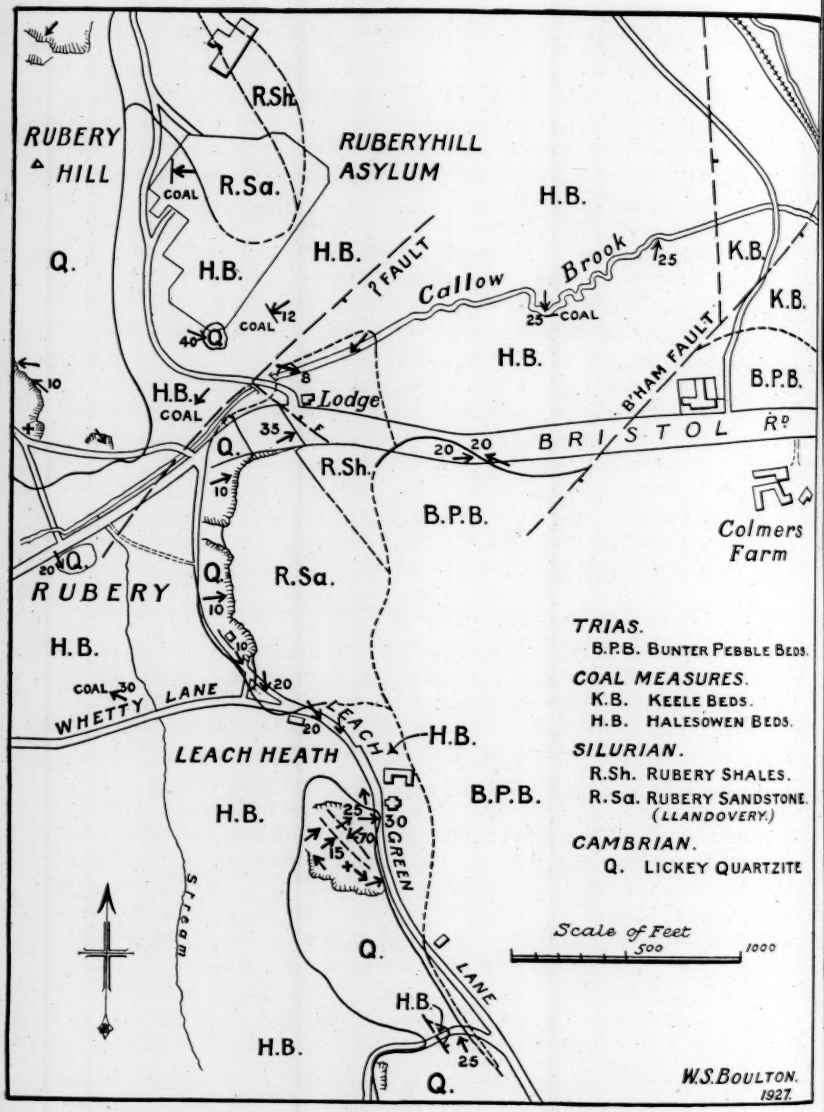

FIG. 1.—Geological sketch-map of the Rubery area of the Lickey Hills.

a depth of 10 feet is purplish-red and sandy, blotched with yellow and bluish patches, and dips at about 20° off the Sandstone, lumps and fragments of the latter lying in the base of the clay. The Llandovery Sandstone rises to within 3 feet of the surface 18 yards south-east of the cottage, and large angular lumps of it make up the base of the clay, but the sandstone floor gradually deepens again until the whole of the trench was occupied by gently dipping yellow, buff and red clay.

For the next 200 yards the trench with its manholes, to a depth of 12 feet, passed through yellow and red-purplish Coal Measure clays, containing fragments of quartzite and sandstone, and dipping at small angles.

At a point 15 yards south of the Library the Quartzite rises to the surface again, in a little easterly spur 11 yards wide, the beds dipping east at about 30°. Red, purplish, and bluish-green sandy clay, with much quartzite rubble in the base, dips steeply off the bedded quartzite on both sides of the knoll, and then gradually flattens out, occupying the trench southward for the next 165 yards, when it abuts against the Bunter Sandstone. A few yards north of this junction the Coal Measure clay is bluish-grey with black coaly matter. The junction of the Coal Measures and Bunter crosses the road obliquely and is clean cut, black stained, and steeply dipping to the south-east.

From this point to the junction of Leach Green Lane and Eachway Lane, a distance of 185 yards, the Bunter Sandstone was exposed to a depth of about 12 feet, covered by an irregular mantle of Drift, consisting of coarse gravel and large blocks of quartzite below and red sandy clay above. The total thickness of the Drift varies from about 12 feet near the Coal Measure junction to about 2 feet near Eachway Lane. In places the gravelly Drift occurs in pockets of the Bunter, in one of which a platy felsite boulder, 3 feet by 2 feet, occurred.

In two manholes at the junction of Leach Green Lane and Eachway Lane, the pebbly Bunter Sandstone with a thin cover of pockety gravelly Drift was exposed, and in the lower few feet of the manholes purple red clay of Coal Measure type, with abundant fragments of Llandovery Sandstone, was visible under the Bunter. Turning westward down Eachway Lane, which cuts across the general axis of the Lickey Ridge, an interesting exposure was laid bare in the deep trench, at a point about 25 yards from the junction with Leach Green Lane (Fig. 2). Typical Bunter Sandstone, which could be followed to this point from the road junction, was exposed to a depth of 14 feet, and is brought abruptly against red Coal Measure clay. The junction is clean cut and darkly stained and dips steeply to the west. The clay is about 2 feet thick at outcrop, but thickened rapidly to about 7 feet at a depth of 10 feet in the trench, and is overlain by solid but broken quartzite, the junction of quartzite and clay being even and clean cut, with a dip westward at about 45°.

Thus the beds have been overturned, and the quartzite is apparently thrust eastward over the Coal Measures, squeezing and almost cutting them out, while the latter are overturned on the Bunter Sandstone. The Quartzite which here dips north at 25°, continues to outcrop westward for about 34 yards, when purple, sandy Coal Measure clay containing angular fragments of quartzite, rests upon an irregular inclined surface of it. The Quartzite is brought up to the surface again 10 yards further west by a small fault with an easterly downthrow. The bedded quartzite, capped by quartzite rubble, then continues for 15 yards, when it is succeeded again by the same Coal Measure clay, dipping off the quartzite, and Coal Measures occupied the whole of the deep trench to the last manhole 34 yards to the west. (See Section, Fig. 2.)

The new evidence obtained from the trench just described, together with that from other trenches and excavations in the area, of which summaries have been previously published (ibid.), now permits of

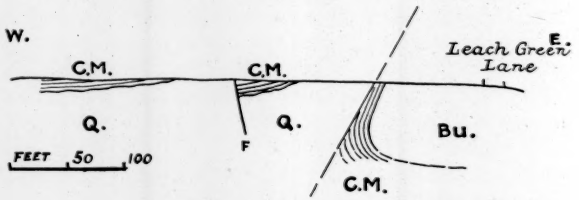

FIG. 2.—Section showing the relation of the rocks exposed in trench at top of Eachway Lane. (Vertical scale exaggerated about four times.)

a more exact determination of the outcrops and inter-relations of the rocks than was formerly possible. The formations may be taken in stratigraphical order :—

1. LICKEY (CAMBRIAN) QUARTZITE.

Excavations for the new extension of Rubery Asylum showed that the Quartzite occurs under a thin cover of Coal Measure clay in the ground due north of the School at Rubery, and on both sides of the main Asylum drive from Bristol Road. Thus, 90 yards north of the School, and again 65 yards still further north, two small knolls of Quartzite rise through the Coal Measure clay mantle. Consequently the main outcrop of Rubery Sandstone which occurs on the eastern flank of the Quartzite south of Bristol Road does not continue northward as shown on the new Survey 6 in. map, but is cut off just north of the road, its normal strike position being occupied by Quartzite, almost entirely covered by a thin mantle of Halesowen Clay. The general easterly shift in outcrop of Quartzite, Rubery (Llandovery) Sandstone and Rubery Shales in the foundations and grounds of the Asylum seems best accounted for by a north-east and south-west fault with a south-east downthrow. (Shown on Map, Fig. 1.)

2. Rubery (Llandovery) Sandstone.

Much of the outcrop of this Sandstone round Leach Heath as shown on the recently published 6-inch map of the Geological Survey must now be replaced by overlying Halesowen Beds; while as stated above, the supposed outcrop of Rubery Sandstone between Bristol Road and Rubery Asylum must give place to the same Halesowen clays resting upon the Quartzite. It is evident from the map (Fig. 1) that the Rubery Sandstone, where it rests upon the Quartzite at Leach Heath is rolling over southward, and the large quantity of sandstone débris in the base of the Halesowen clay on the west flank of the Quartzite (referred to on p. 255) suggests that the Rubery Sandstone may occur in situ on this west side and partake of the general anticlinal structure of the Quartzite ridge. The most southerly exposure of the Sandstone under the Coal Measure cover seen in the trench was near the house about 198 yards north-east of the top of Whetty Lane. South of this point, the only known outcrop of Llandovery Sandstone is a knoll about 165 yards north-west of Rednal House surrounded by Bunter Pebble Beds, and beyond the margin of the map, Fig. 1.

Wherever the Rubery Sandstone has been seen, its relation to the Quartzite is the same as in the well-known exposures at Rubery, where the unconformable junction with the Quartzite is irregular and marked by many water-worn quartzite pebbles and boulders near its base.

3. Coal Measures.

One of the outstanding facts revealed by the new evidence is the much greater spread of Coal Measure clay over the Quartzite and Llandovery than was formerly supposed. At Leach Heath and in Eachway Lane the Coal Measures invade hollows and gullies in the older rocks, while at Rubery the clays breach the Quartzite ridge along the line of Callow Brook, and then spread out north and east as a thin ragged mantle over the older rocks, joining up with the large spread of Halesowen Beds to the east of Rubery Hill and between Callow Brook and the River Rea. It is likely that the Coal Measures of Leach Heath extend unbroken in an easterly direction under the Bunter and join up with the Coal Measures proved in the Bristol Road trench (Fig. 3).

Wherever the base of the Halesowen Beds is visible there are abundant rock fragments, usually small angular chips, but sometimes large angular blocks of either Quartzite or Llandovery Sandstone according to its underlying formation. At two places between Bristol Road and Rubery Asylum a coal seam was met with, doubtless the same seam as that exposed to the north-west of the Asylum (op. cit., p. 61).

As we pass southward to Leach Green and beyond to Eachway Lane, no satisfactory junction marking the oncoming of Keele

Beds could be seen. On the whole, red, purple, yellow, and blue are the predominant colours hereabouts, with occasional coaly smuts, and sometimes a lilac-blue clay makes its appearance. The clays between Leach Heath and Eachway Lane are probably near the top of the Halesowen Beds. The Halesowen clays which fringe the western side of the Quartzite pass up gradually into the Keele Beds as we pass south of Eachway Lane, possibly due to the fact that submergence of the Cambrian and Silurian rocks in Coal Measure time took place gradually and progressively from north to south. On the other hand, a differential tilt in post-Coal Measure time, with relative elevation and subsequent greater denudation in the northern part of the range would also account for the facts. If the latter is the true interpretation, the Halesowen Beds should occur under the red Keele clays which flank the Quartzite on the south-west side of Rednal Hill and Bilberry Hill.

The Coal Measure clay, containing a Spirorbis Limestone, discovered in 1924 in a trench during the widening of Bristol Road between the Birmingham Fault and the Rubery Shales (op. cit., p. 64) is of interest in connection with the Coal Measures now known to extend over Leach Heath and also between Bristol Road and Rubery Asylum. These red and buff mottled clays with Spirorbis Limestone were provisionally placed in the Keele, partly because of the red colour of much of the clay and also because the contained Spirorbis Limestone is similar to other Spirorbis Limestones found in the Keele Beds along the southern fringe of the South Staffordshire Coalfield. The clays found in the road trench are about 170 yards from the blue and grey Halesowen Clays, with a thin coal exposed in Callow Brook to the north, but it is difficult to measure the stratigraphical interval between the two exposures because the beds hereabouts are disturbed and rolling. In recording this exposure in 1925 the writer assumed a possible small east-west fault between Bristol Road and Callow Brook, separating the Halesowen Beds to the north from the clays with Spirorbis Limestone in the road. The difficulty is to fix the horizon of this Spirorbis Limestone. It is very unlikely from its position that it is the same limestone which occurs in bright red clay, 120 feet above the 30 feet sandstone (Hunnington) on the south of Hollymoor Asylum (op. cit., pp. 65–6). Again, it has generally been assumed that the Illey Brook Limestone in the Upper Halesowen Beds is distinguishable from the blue-grey limestones in the Keele by its dirty white or putty colour. Recently, however, Dr. L. J. Wills has obtained specimens of the Illey Brook Spirorbis Limestone in situ in a trench-cutting on the Halesowen-Romsley Road, 150 yards south of Oatenfields Farm, which are blue-grey in colour, and the rock is not unlike the Spirorbis Limestone from the road trench at Rubery.

Up to the present it has not been found possible to correlate the Halesowen Beds of Rubery with those of the type area south of Halesowen. It is probable that the red and yellow mottled clays

associated with the Spirorbis Limestone in the Bristol Road trench lie above the blue and grey clays with thin coal exposed in Callow Brook, less than 200 yards to the north, and that the former lie near the top of the Halesowen Beds, if not actually in the basal beds of the Keele.

The sub-Bunter outcrop of the Spirorbis Limestone probably runs east of the Birmingham Fault and a little south of Colmers Farm. It should also outcrop along the northern fringe of Balaam's Wood, which is a little to the north of the map (Fig. 1), but so far it has not been seen there.

There is as yet insufficient evidence to show whether more than one coal seam is present in the Halesowen Beds in the Rubery area. A seam 2 feet thick is said to have been worked at one time at or near the village of Rubery. The Coal which the writer saw exposed in the trench between Callow Brook and the Asylum (p. 259) was about 1 foot thick, and is probably the same as that exposed on the north-west side of the Asylum, which is about the same thickness. The Coal exposed in Callow Brook (marked on map, Fig. 1) is about 6 inches thick.

With the evidence now available, one is tempted to assign a stratigraphical position for the blue and grey clays with the Rubery Coal seam or seams, as equivalent to that of the Wassel Grove Coal series of the Hayley Green district north of Hagley Wood. The Limestone in the Bristol Road trench might then correspond to the Limestone, of which fragments have been found in Turnpike Coppice, to the north-east of Hagley Wood and just north of the Hagley-Birmingham Road. The Survey doubt whether this latter is the same as the Illey Brook Limestone, which they are inclined to assign to a somewhat lower position, and associated with the Wassel Grove Coal. But if the correlation now suggested be correct, it would mean that the Spirorbis Limestone in Bristol Road is high up in the Halesowen Beds, and either equivalent to that of Illey Brook or not far above it.

4. Bunter Sandstone.

Observations made during the widening of Bristol Road between Longbridge and Rubery (op. cit., p. 64) proved that Bunter Pebble Beds occupy the ground round Colmers Farm and the Leys. This is shown as Enville Beds (Calcareous Conglomerate Group) on the new Geological Survey 6 in. map (see map, Fig. 1). Moreover, the writer has failed to find any evidence of this Calcareous Conglomerate Group north-east of the railway, where it is shown by the Survey, faulted to the north-west against Keele Beds. There are bright red clays visible in places, especially near the base of the Bunter close to the railway, so that the evidence such as it is points to Keele Beds and not to the Calcareous Conglomerate Group as outcropping here, and underlying the Bunter to the eastward.

The Birmingham Fault.

As previously recorded (op. cit., p. 64) the Birmingham Fault, bringing down Bunter on the east against red and blue Coal Measure clay on the west, crosses the Longbridge-Rubery Road 108 yards west of the School House near Colmers Farm.

A notable fact now established is that this fault does not continue southward across the Lickey Hills as shown on the Survey 1-inch map (1897), and as is drawn on the new 6-in. Survey map. Every foot of the longitudinal trench section from Rubery to Eachway Lane was carefully examined during the whole time the excavations were in progress, and naturally the Leach Heath section, where the fault is drawn as crossing on the new 6 inch Survey map, was specially noted, but no break in the Quartzite, Llandovery Sandstone, or Coal Measures could be detected. In the low ground at Leach Heath the Rubery Sandstone, with a thin cover of Coal Measures, is resting on the Quartzite in a narrow, east-west unfaulted syncline. The throw of the fault where it crosses Bristol Road must be small, and it apparently dies out before the Lickey Ridge is reached.

It is now possible to correlate the new data referred to above with observations made nearly a hundred years ago, and about which

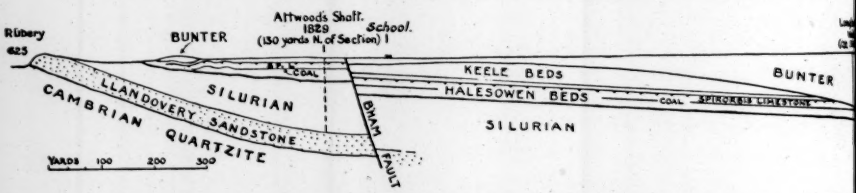

Fig. 3.—Section along Bristol Road between Rubery and Longbridge.

there has been some doubt in recent years. In 1829 James Yates recorded the fact that " at Colmers Farm[1] . . . a bed of pure limestone is worked about 2 feet in thickness and 8 feet from the surface of the ground. A red stiff marl lies over it, and beneath it is a similar marl variegated with blue ".[2]

There can be little doubt that the limestone referred to by Yates is the same as the Spirorbis Limestone recently exposed in the road trench (p. 260), but all trace of the old workings he mentions has long since vanished. Yates further states that " at a short distance to the east of this limestone, and at the base of a hill called Leach Heath, a shaft has been sunk to a depth of 125 yards ". It is probable that the site of this old shaft is about 150 yards to the north of the School and near the present Filter Beds. The thickness of the Coal Measures and Silurian referred to in his description is not given, and therefore the base of the Halesowen Beds in the section (Fig. 3) is uncertain;

[1] It should be noted that Colmers Farm was formerly much more extensive than now, and embraced a large area to the north-west of the present farm.

[2] Transactions of the Geol. Soc., vol. ii, second series, 1829, p. 256.

but the Silurian rocks are said to extend to a depth of "above 100 yards from the surface", and further on (op. cit., p. 258) he says that the quartz rock (presumably Llandovery Sandstone) was met with in the shaft at a depth of more than 100 yards from the surface. The position of this shaft is indicated in the section (Fig. 3), as is also the well and boring at the Longbridge Pumping Station, in which Silurian Shales ("Blue Binds") occur from a depth of 357 to 496 feet (the bottom of the boring). Above this are red and blue marl with coal fragments and "pebbles", which no doubt belong to the Halesowen Beds, while above them are about 300 feet of Bunter and overlying Drift. The section (Fig. 3) shows that the Keele Beds which emerge from the base of the Bunter and outcrop a little to the north, are overstepped by the Bunter about 130 yards west of the Longbridge Pumping Station, while the Halesowen Beds are similarly overstepped about 200 yards to the east of it. Thus, while the Coal Measures on the eastern flank of the Lickey Hills are probably absent under the Bunter south-east of the road which runs from Longbridge to Rednal, they extend, possibly for a considerable distance, under the Bunter north of the Bristol Road between Longbridge and Colmers Farm.

South-east of the Longbridge-Rednal road Silurian rocks probably occupy much or all of the sub-Bunter ground up to the Silurian outcrop at Kendal End. Still further south-east of this one might expect the sub-Triassic floor to reveal Cambrian and pre-Cambrian rocks, of which the outcrop of the Lickey Hills is but a small fraction.

Overfolding and Thrusts.

The evidence of overfolding of the Quartzite, Coal Measures, and Bunter near the top of Eachway Lane (described on p. 257) is of some interest, and may be related to other evidence of thrust-faults and crush-belts to be seen to the north and south of Eachway Lane.

At the north-east corner of an old quarry in the Quartzite, 370 yards north-north-west of the top of Eachway Lane, two roughly parallel faults with a north-west bearing and about 50 feet apart, can be seen, and are marked on the Survey new 6-inch map. The Quartzite dips 70° to the south-west between the faults, while the dip on the north-east of the faults is to the north-east at about 25° and on the south-west of the faults it is 15° to the north-east. This can be explained by a south-westerly thrust which is nearly in line with the overturned and thrust junction of Quartzite and Coal Measures in Eachway Lane, and extending north-north-west nearly parallel to Leach Green Lane. (See Fig. 4.)

Crush-belts, varying in width from a few feet to several yards, are met with at intervals in the Quartzite of Leach Green Quarries. They all have a general north-west, south-east bearing with a high dip to the south-west.

Reference may also be made to the thrust-fault which strikes

north 30° west, near the base of the Rubery Shales seen in the road widening and trenches in the Bristol Road, Rubery.[1]

Other evidence of overthrusts in the Quartzite can be seen near the base of the large quarry on the north side of Rednal Gorge and about 900 yards south of Eachway Lane. Two adjacent thrusts converging eastwards are here exposed, the upper inclined to the west at 18° and the lower at 25°. Eastward they end rather abruptly against a vertical shatter belt in the quartzite. (Fig. 5.) Similar thrusting from the west is visible in the quarry on the south side of the gorge, but the beds are there more shattered. The finest

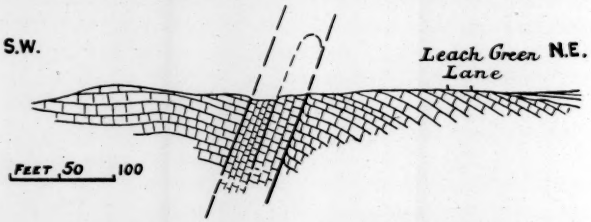

FIG. 4.—Section showing thrust belt in quartzite quarry, near Library, Leach Heath.

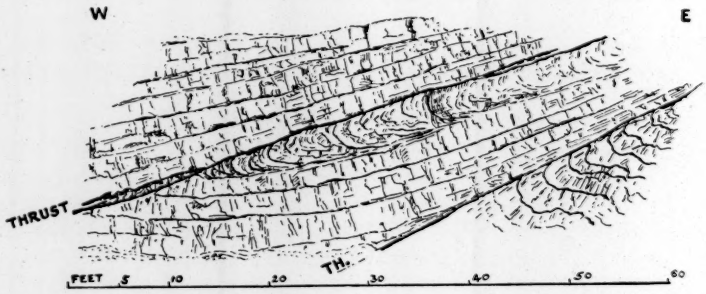

FIG. 5.—Sketch showing two thrust-planes in quartzite at base of quarry, north side of Rednal Gorge.

example of overfolding in the Lickey Hills is that which is exposed in the large quarry further south, on the east side of Bilberry Hill near the road from Rednal to Barnt Green. This exposure has been known for many years. The beds in the upper 20 feet of the quarry-face are sharply bent over from south-east to north-west into small, recumbent, sigmoidal folds. The plane of separation between the overfolded beds and their downward continuation, where they dip abruptly in the opposite direction, is undulating and nearly horizontal. (Fig. 6.) At the south end of the quarry the overturned beds are faulted down to the south-east. The structure is obviously due to intense compressive stress, and it seems necessary

[1] Op. cit., p. 71, and Fig. 2.

to postulate either a thrust from the south-east, or a more deep-seated thrust from the north-west, with a lag in the higher beds when a thick cover of rocks existed at the time of the thrusting movement.

Whenever the thrust movements just referred to had their origin, the overfolding and thrusting revealed in the trench sections in Eachway Lane indicate a post-Triassic date for some, at least, of it. Intense compressive movements of post-Permo-Carboniferous age have been seldom recorded in the Midlands, so that this instance is of interest. It probably reflects a marginal phase of the great Alpine movement of Western Europe, but whether of late Mesozoic or of Tertiary date is not certain.

The writer has thought that the effect of similar thrusting from the west may have been responsible for the remarkable structure

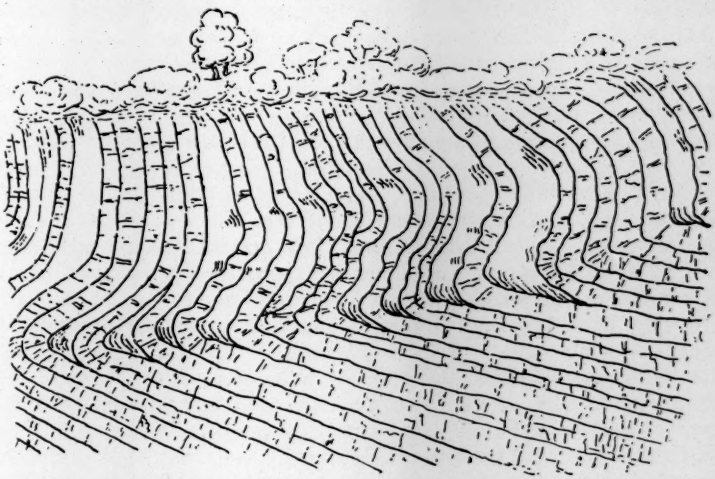

FIG. 6.—Overfolding in quartzite in quarry on east side of Bilberry Hill. The sketch shows the top 30 feet of central part of face, looking S.W.

in the vicinity of that portion of the Russell's Hall fault which lies south of Dixon's Green, south-east of Dudley, in the South Staffordshire Coalfield and some 7 miles north of the Lickey Hills. This fault-belt with the adjacent Dudley-Rowley Ridge to the east of it, can be regarded as a structural continuation of the Lickey Hills. The sudden change in throw of the Russell's Hall Fault from south-west to north-east, and the curious deep trough in which the Thick Coal has been found, tucked in, as it were, under the Rowley Dolerite Hills, is very suggestive of an intense squeeze from the west. May it not be that this deep-seated squeeze in post-Permian time was responsible for the intrusion of the Rowley-Dolerite laccolite into the Etruria Marls, as well as similar and smaller intrusions in this Coalfield; and the striking narrow trough immediately

north of Yewtree Colliery,[1] may be a subsidence which followed in the wake of the squeeze out of the basic magma into the laccolite.

Finally, it is interesting to note the great antiquity of the Lickey Ridge as an outstanding buttress against which lapped successive Palaeozoic seas, and along which marginal basal sediments were deposited. On the south-east flank of the Quartzite, in the large quarry with the overthrust, a coarse gritty and conglomeratic type of quartzite can be seen, full of rounded fragments of the underlying Uriconian volcanics. The Llandovery Sandstone, as we have seen, exhibits an unusually fine conglomerate base with rolled quartzite pebbles and boulders fringing the irregularly eroded quartzite cliffs. The Halesowen Beds of the Coal Measures also show signs of a marginal fringe. But in this last case, the waters in Upper Coal Measure time quietly submerged the older rocks with an absence of turbulent wave action and erosion. For wherever the base of the Coal Measures is seen, and it has been closely examined at many places, the basal clays contain abundant large and small, but quite sharp-edged and angular lumps of quartzite and sandstone, the aerially-denuded débris of the land of the period, which was quietly submerged or which fell into the shallow water of the time.

The Cambro-Silurian ridge assumed an anticlinal structure and formed part of a land surface which was deeply denuded during Devonian and early Carboniferous time. It was partly submerged in Halesowen time, but was probably completely covered by the Keele Beds, and possibly by an overlying Calcareous Conglomerate Group. Then followed prolonged denudation and elevatory movements during the arid period when the Clent Breccias were accumulated, composed chiefly of Cambrian, Silurian, and pre-Cambrian rocks of the Lickey core and other ancient ridges now buried from sight. After that came the desert sands and shingle beds of the Bunter, whose basal rocks, with their occasional angular blocks and fragments of quartzite and Llandovery Sandstone, fringe the Lickey Hills on the east and south, and testify that the quartzite core of the ridge had again been laid bare by Triassic time.

No rocks newer than the Bunter, except the Glacial deposits, are now present in the immediate neighbourhood of the north end of the Ridge to record subsequent events, but these Bunter Beds, as shown on p. 262, have suffered faulting and other disturbances, and on the eastern flank of the Ridge have been thrown into gentle synclines and anticlines with a pitch to the south-east.

I wish to thank Mr. W. H. Laurie, of the Geological Department of the University of Birmingham, for re-drawing the map and sections which illustrate the paper.

[1] " The Geology of the Southern Part of the South Staffordshire Coalfield " : *Mem. Geol. Surv.*, 1927, pp. 160–3.

Post-Glacial Fossil Mollusca from a Delta Deposit at Winnipeg, Manitoba.

By Alan Mozley, University of Manitoba.

(PLATE IX.)

THE fossil deposit here described is situated on the west bank of the Red River, 3 miles (in a direct line) south of its junction with its western tributary, the Assiniboine River. More specifically the deposit is situated about 50 yards from the residence built by the late Colonel Thompson in Fort Garry, a suburb on the southern outskirts of the city of Winnipeg.

At this point the west bank of the Red River is being eroded at a fairly rapid rate and as a result a good section, some 25 feet from low-water level to the top of the bank, is exposed. The lower half of this section is covered by talus from the bank above, but a fresh section can be uncovered with a little labour.

The material as exposed is a silty clay, ranging from a light to a dark grey in colour, and varying considerably in composition. Extremely thin layers of a light grey clay are sometimes found interleaved with a coarse silt. The section exhibits rough horizontal stratification and cross bedding was noted at one point. At a depth of 8 feet a thin but clearly marked and continuous stratum of charcoal is found, probably representing the drift from an old forest fire.

The beds are Recent or Post-Glacial in age and have evidently been laid down in delta flood plains.

Twenty-six specimens of molluscs, including one new variety (*Amnicola winkleyi mozleyi* Walker) (see Walker, 6)[1] was found in the deposit. Two species, *Vallonia parvula* St. and *Segmentina crassilabris* Walker, are reported as fossils for the first time. Of the remaining twenty-three species only three appear to have been previously recorded as fossils in Canada. The species present are in general widely distributed in Western Canada at the present time with the exception of *Vallonia parvula* St., which has only once been previously recorded from Canada (see Walker, 5). *Segmentina crassilabris* Walker has been found in a number of Manitoban localities by Mozley (3 and 4), but the extent of its distribution in this drainage is not known. As has been noted above, this is the type locality of *Amnicola winkleyi mozleyi* Walker, the types being from Bed IV. It is of interest to note that even in this northern situation circumboreal forms are in the minority. When the habitat preferences are considered it is seen that most of the species present are those which usually inhabit protected situations, marshes, ponds, and smaller lakes, with the addition of

[1] Figures in parentheses refer to List of References at end of paper.

some creek and river forms. The terrestrial species are the same as those which inhabit moist poplar forests in Manitoba at the present time. Pieces of charcoal present in some of the beds, particularly Bed IV, have been examined by Mr. C. W. Lowe, of the Department of Botany, University of Manitoba, and pronounced to be of poplar wood, or something very similar. The predominance of marsh forms, with the addition of half a dozen terrestrial species and a single species often found in deep water, indicate that the deposit was formed by drift from a number of different habitats. The silt in which they are embedded appears to be a delta formation, and the fauna indicates a similar association of habitats, so that the deposit may have been laid down by one of the rivers running into the lakes formed during the period when Lake Agassiz was being drained, and after the waters of this drainage had acquired their fauna from the Mississippi.

DISTRIBUTION OF MOLLUSCA IN A SILT BED NEAR WINNIPEG.

Bed No.	I.	II.	III.	IV.	V.	VI.	VII.	VIII.
Depth below top of sod	3′	5′ 3″	7′ 2″	8′ 4″	10′ 4″	13′ 11″	15′ 5″	16′ 7″
TERRESTRIAL SPECIES.								
Vallonia costata	×	×	×	×	×	—	×	×
Vallonia parvula	—	×	×	—	—	—	—	—
Polita hammonis	—	—	×	×	—	—	—	—
Pyramidula c. anthonyi	—	×	×	×	×	—	—	—
Succinea ovalis	—	—	—	×	—	—	—	—
Succinea sp.	—	—	—	×	×	—	×	×
AQUATIC SPECIES.								
Lymnaea obrussa exigua	—	—	×	—	—	—	—	—
Lymnaea vahlii arctica	—	—	×	×	—	—	—	—
Lymnaea caperata	—	—	—	—	—	—	×	—
Planorbis parvus	—	×	×	×	×	—	×	—
Planorbis sp.	—	×	—	×	—	—	—	—
Segmentina crassilabris	—	—	—	×	—	—	—	—
Physa integra	×	×	×	×	×	—	—	—
Aplexa hypnorum	—	—	—	—	×	—	—	—
Ferrissia rivularis	×	×	×	×	×	—	×	—
Amnicola limosa	—	—	—	—	×	—	—	—
Amnicola emarginata	×	×	×	×	×	×	×	×
Amnicola winkeleyi mozleyi	—	×	×	×	×	—	×	×
Valvata tricarinata	—	—	×	×	×	—	—	×
Sphaerium solidulum	—	—	—	×	×	—	—	—
Sphaerium stamineum	—	—	—	×	×	—	—	—
Sphaerium emarginatum	—	—	—	—	×	—	×	—
Sphaerium notatum.	—	—	—	—	—	×	—	—
Sphaerium torsum	—	—	—	—	—	×	—	×
Sphaerium acuminatum	—	—	—	—	×	—	×	—
Sphaerium straitinum	—	×	—	×	—	—	×	—
Musculium transversum	—	—	—	×	×	—	—	—
Pisidium compressum	—	—	—	—	×	—	—	—
Pisidium fallax	—	—	—	×	—	—	—	—

Amnicola winkleyi mozleyi Walker. Paratypes in the Collection of the Author. Male and Female Shells.

[*To face p. 268.*

I take pleasure in acknowledging the aid of Mr. A. A. McCoubrey with the geological part of this work, and that of Drs. Brynant Walker, F. C. Baker, and Victor Sterki, in the determination of certain of the shells. Dr. Sterki also very kindly supplied some data regarding the ecology of the Sphaeriidae.

Gastropoda.

Vallonia costata (Mull). Beds I, II, III, IV, V, VII, VIII, not common.

Vallonia parvula St. Beds II, III. Rare.

Polita hamonis (Strom.). Beds III, IV.

Pyramidula cronkhitei anthonyi Pils. Beds II, III, IV, V.

Succinea ovalis Say. Beds IV. Reported as a fossil from Eastern Canada.

Succinea sp. Broken fragments of another species of *Succinea* were found in Beds IV, V, VII, VIII.

Lymnaea obrussa exigua Lea. Bed III. Rare. Habitat Preference: Bayous, ponds, lakes, and protected shores of streams.

Lymnaea vahlii arctica Lea. Beds III, IV. Rare. Habitat Preference: Marshy situations.

Lymnaea caperata Say ? Beds VII. Habitat Preference: Sloughs, ponds, intermittent streams.

Planorbis parvus Say. Beds II, III, IV, V, VII. Not common. Habitat Preference: Protected situations, marshes, etc. Reported as a fossil from eastern Canada.

Planorbis sp. Beds II, IV. Very young individuals of another species of *Planorbis* (*trivolvis* Say ?).

Segmentina crassilabris Walker. Bed IV. Habitat Preference: Usually a shallow water form. Bottom of Lake Nipigon, Ont., 45 feet, dead—Adamstone (1).

Aplexa hypnorum Say. Bed V. Habitat Preference: Marshes.

Physa integra Hald. Beds I, II, III, IV, V. Habitat Preference: Exposed shores, protected situations, rivers, creeks, small (?) lakes.

Amnicola limosa Say. Bed V. Habitat Preference: Usual habitat, sheltered bays on sandy bottom in shallow water (Baker, 2).

Amnicola emarginata Kuster. All beds. The most abundant species, very common. Habitat Preference: Water more than 10 feet deep.

Amnicola winkleyi mozleyi Walker. Beds II, III, IV, V, VII, VIII. Common. Habitat Preference: Not known.

Valvata tricarinata Say. Beds III, IV, V, VIII. Habitat Preference: Marshes, also in deep water.

Ferrissia rivularis Say. Beds I, II, III, IV, V, VII, VIII.

PELECYPODA.

Sphaerium striatinum Lam. Bed II, IV, VII. Habitat Preference: Generally in rivers and creeks and smaller lakes, especially those fed by streams.
Sphaerium solidulum Prime. Beds IV, V. Habitat Preference: Running water, mostly rivers and creeks.
Sphaerium stamineum C. Beds IV, V. Habitat Preference: as *solidulum* Prime.
Sphaerium acuminatum Prime. Beds V, VII. Habitat Preference: Smaller lakes and ponds.
Sphaerium notatum St. Bed VI.
Sphaerium emarginatum P. Beds I, VI, VII.
Sphaerium torsum St. Beds VI and VIII.
Pisidium fallax St. Bed IV.
Pisidium compressum Prime. Bed V.
Musculium transversum P. Beds IV, V. Habitat Preference: Rivers and Creeks.

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The Magmatic Origin of Ores.

By R. H. RASTALL.

OF late years a great deal has been written on the genesis of ore-deposits, and in particular much space has been devoted to more or less controversial discussions of the possibility of a magmatic origin for many important types, both in individual instances and by way of generalizations. The widespread acceptance in many quarters of a belief in the derivation of such deposits on a wholesale scale from igneous magmas may perhaps to some extent be regarded as a natural reaction from some of the theories of markedly contrasted character that prevailed almost universally in past times. The "swing of the pendulum" is such a well-known psychological phenomenon that it is unnecessary to enlarge on it here. It is applicable to nearly all branches of knowledge, and of

ignorance, and was long ago summarized in the law that action and reaction are equal and opposite. If a theory is pushed too far, it is inevitable that in a while it will be regarded as wholly, or for the most part, erroneous, although it may nevertheless contain a good deal of truth. Most of these difficulties and controversies arise from the ineradicable habit of generalizing too broadly, and the rest of them can generally be traced to misunderstandings as to the precise meaning of the terms employed. In the history of the scientific study of ore deposits both of these sources of error have undoubtedly played an important part.

The origin of ore-deposits first attracted serious attention in Germany, and many of the ideas put forward during the pre-Wernerian period, beginning with Agricola (*De Re Metallica*, 1556) have a strangely modern ring, when allowance is made for the peculiar terminology employed by some writers. They were in the main "ascensionists", as they attributed the ore to metal-bearing emanations due to "fermentations" in the bowels of the earth. The occurrence of replacement was also recognized, although it was called *transmutation*. A retrograde step was taken by Werner, who argued that as lodes often diminish downwards, they must have been filled from above or from the sides, and this view is in reality the parent of the theory of lateral secretion, which loomed so large in the middle of the nineteenth century, under the leadership of Bischoff, Forchhammer, and Sandberger.[1]

The earlier attempts at the classification of ore-deposits were very largely of a practical nature, adapted to the needs of the mining engineer rather than of the geologist: they were concerned mainly with the form of the deposit rather than its origin, but with the growth of the purely scientific spirit and the influence of evolutionary ideas, a need was felt for the correlation of morphological and genetic conceptions. A notable landmark of this period was the publication of Breithaupt's remarkable little book *Die Paragenesis der Mineralien* in 1849. But the main development of the subject took place in America in the hands of that brilliant band of workers who have done so much to enhance the dignity of economic geology, and to raise it to the status of a first-class branch of science. Much work of first-rate importance was also done in Norway, Germany, and France, which is known to all students of the subject. Without entering into detail it may be said that the tendency during the first quarter of the present century has been more and more to magnify the importance of direct magmatic processes as the causes of mineralization, as a study of the voluminous literature of the period shows very clearly: perhaps this has been pushed too far, and at the moment there are signs of a reaction. The principal object of the present paper is to investigate the causes of this reaction

[1] This paragraph is condensed from Dr. Hatch's Presidential Address to the Institution of Mining and Metallurgy, 1914.

and to consider whether to some extent it is the result of a misunderstanding of what is meant by the term " magmatic ".

The general process of the cooling and consolidation of a large-scale magmatic intrusion may be envisaged as taking place somewhat on the following lines. First of all let us assume that the necessary amount of intratelluric differentiation has taken place, and that the intrusion in question has the general composition of a granite for example. There can at any rate be no doubt that intrusions of granite have occurred and that they have been accompanied by ore-deposit. Even the most fanatical adversaries of magmatic ore-formation will doubtless concede this point. If not, they may well go to Cornwall and see for themselves. A few days spent at Camborne or Redruth should convince them.

First of all then we have the consolidation of the main mass of the granite, which may perhaps be roughly estimated as amounting to something like 99 per cent, or possibly even to 99·9 per cent of the whole. Precise figures are always dangerous, but on the basis of F. W. Clarke's estimates, let us take 99·0 per cent as consolidating in the form of quartz, felspar, and mica, chiefly as the main intrusion, but with a certain residuum which lags behind and manifests itself at some later stage as hypabyssal intrusions of quartz-porphyry dykes. (The possibility of the differentiation of this residuum into acid dykes and lamprophyres is here disregarded, although it undoubtedly often occurs.) As a result of this crystallization-process there is concentrated within the intruded mass a residual mother-liquor containing all the constituents of low freezing-point, and all the elements capable of forming with them compounds of low freezing-point (volatile constituents), that were present in the original magma (*Die flüchtigen Bestandteile* of Niggli).

This residuum may at first be disseminated more or less evenly within the meshes of the crystal-sponge as envisaged by Harker, or it may be concentrated more or less in spots and patches. Again, to follow up the idea of Barrow and Harker, it may be squeezed out of the sponge by earth-movements, perhaps being forced along in front of an earth-wave. There is also another important alternative : as the main mass of the granite cools down its volume will diminish, and cracks will be developed, forming open joints, such as can be seen in any granite quarry. Along these open joints the residual fluid can escape, sometimes setting up far-reaching changes in the walls of the cracks : e.g. the greisen-lined veins of St. Michael's Mount and Cligga Head, where the occurrence of such a process is obvious. The final fillings of these fissures are mineral veins, rich in wolfram, etc., at the places mentioned.

The different processes just outlined, given the requisite constituents in the fluids, are obviously competent to give rise to all the phenomena commonly classified as pneumatolytic : tourmalinization, greisening, kaolinization, topazization, and all their various

combinations and modifications in the case of acid rocks, as also scapolitization and serpentinization in basic rocks, where the elements present are different, but the principles the same. Closely allied to all these are the various types of alteration so common in lavas (sericitization, propylitization, and so on). Probably also many occurrences of secondary albite belong here.

It is unnecessary to enter into any more detail. The point here to be emphasized is that all the phenomena of this class are a natural and inevitable consequence of the cooling and crystallization of a magma containing what are commonly called volatile constituents, as all magmas undoubtedly do, although obviously of very varying amount and different character. Each intrusion has its own chemical peculiarities.

It is hardly necessary, either, to labour the point that these same pneumatolytic fluids produce very important changes in the rocks surrounding the intrusion. The general principles are precisely similar.

There can clearly be no justification for denying the title of magmatic to these processes: they are due to agents derived from the intrusion itself, segregated during the process of its crystallization and many of them are initiated, even if not completed, long before the final solidification.

It now remains to consider the relation of such a scheme of magmatic crystallization to ore-deposits. We shall not here discuss the vexed question of the origin of the great sulphide masses, or their possible segregation from magmas on the principle of immiscible liquid phases. Neither will any space be devoted to the origin of chromite and platinum from ultrabasic magmas. Attention will be confined mainly to the origin of metalliferous veins in and near intrusions.

It must, however, be pointed out first of all that certain ore-minerals do occur disseminated in plutonic rocks, playing the part of accessory minerals of the usual kind. It is for example impossible to draw any distinction between the common occurrence of magnetite, apatite, sphene, zircon, monazite, and so on in small quantities in granites, and the precisely similar occurrences of disseminated cassiterite in such granites. Again in basic rocks we find ilmenite, apatite, and sulphides as early-formed constituents, disseminated throughout the mass of the rock, and not apparently due to any process of segregation. All of these belong to the first stage, the crystallization of the main mass, and prove that the magmas do contain primary metals and sulphides. Reference may also be made to the analytical determination of minute traces of numerous metals in such rocks, as always quoted in support of the theory of lateral secretion.

The next stage, which is of much more significance, is the common occurrence of metalliferous minerals in dykes and pegmatitic intrusions, especially the latter. It is hardly necessary to quote

specific instances, but general reference may be made to the common association of the tin-tungsten parageneses and of the rare-earth parageneses with pegmatites. In the first-named we have a definite association of elements, Sn, W, Mo, Bi, As, with often a good deal of Cu, clearly in genetic relationship to a definite stage in the crystallization-differentiation of magmas of a particular type: i.e. granitic. With them are found F, B, Li, and so on. In certain cases there are also niobium, tantalum, and others, as well as beryllium in beryl. The cryolite occurrence in Greenland is here of particular significance: it appears to be clearly pegmatitic, and carries not only Sn, W, Nb, Ta, and so on, but also a considerable amount of copper, zinc, lead, and iron carbonate. Granted that this is a very peculiar case, nevertheless it is an ore-deposit in every sense of the term, and its magmatic affinities can scarcely be questioned. Certain remarkable pegmatites in the Black Hills of Dakota and Barringer Hill, Texas, belong to a similar category.

From innumerable instances it is clear that magmas contain metals at the pegmatitic stage of differentiation, and these metals for the most part belong to the earlier and deeper zones of the normal sequence. The gold-silver (telluride), antimony, mercury sequence does not seem to appear under these conditions, at any rate in the pegmatites which are rich in felspar or mica. It is of course another and a large question whether any real distinction can be drawn between the undoubted metalliferous pegmatites and, for example, many large gold-quartz veins. As much difference of opinion has lately been expressed on this point the subject will not be further discussed here.

We now come to the type of ore-deposit, or rather to the group of types which have given rise to the greatest divergence of view; namely, the lodes and veins. It is here that we are specially up against the conception of ore-formation by waters of meteoric origin, either by the process of lateral secretion, or by the reascensionist modification of it. At the present time the pure dogma of lateral secretion probably has few adherents, although it seems to linger in the Mississippi Valley. After all, this is not altogether surprising as the State of Missouri is very near Tennessee. Again the reascensionist theory is very difficult to swallow, as it is hard to see why the same water should travel both up and down in the same area; it is unlikely that the natural fissures in the rocks are arranged like the passages in a tube station.

But at this date it is generally accepted that ore-deposits of the type just mentioned are for the most part due to ascending solutions. Of course exception must be made of the concentrations and rearrangements, undoubtedly due to surface waters, that go on in the oxidation and cementation zones (secondary enrichment and so forth). Reference is now made entirely to the phenomena of primary deposit. First of all we have to take

into consideration the fact that vein-formation and vein-filling are often accompanied by a great amount of alteration of the wall-rock, so much so that by many writers very great stress is laid on the idea of replacement as the principal type of ore-deposit. Without offering any comment on the validity of this conception, it may be pointed out that replacement in itself implies great chemical activity in the solutions concerned, and probably in most cases a high temperature, for cold solutions act but slowly on any rock, except perhaps on limestones. Then again we have the exceedingly common occurrence of such minerals as tourmaline, topaz, and fluorite in mineral veins, the last-named being found in enormous quantities, often along with barytes, in the lead-zinc veins of the very type usually cited as characteristic of mineralization by meteoric waters. Then again, to take another extreme case, we have in many instances the obvious association of gold, silver, mercury, etc., with highly heated waters (Comstock Lode; Steamboat Springs; Sulphur Bank, California; gold in geysers in New Zealand).

But it is useless to go on labouring the argument; the crux of it is this. If such ore-bearing solutions are not magmatic, where did they come from? To call them hydrothermal, and thereby to deny the magmatic origin of the ores, is mere quibbling, arguing about definitions and nomenclature rather than about facts. If it seems good to the united wisdom of geologists to decide that the latest stages of the cooling of a magma are not magmatic, let it be so; but it is not logical and it is not scientific.

It must not, however, be supposed that it is here implied that all vein-deposits are even hydrothermal in origin, if this name is preferred for this particular phase of deposition. There are many instances that are difficult to explain on this (or any other) hypothesis. Let us take for example the lead-zinc ores in the Carboniferous rocks of northern England, from Derbyshire to Northumberland. Such igneous rocks as exist in this area seem inadequate to account for them. In Derbyshire they are not large in total bulk, and basic; some of them very much so: e.g., the olivine-dolerite of Bonsall. These, and the toadstones, do not fit in at all well with the enormous amounts of fluorite and barytes that accompany the ores. The first of these minerals belongs, as we believe, to a totally different petrographical type, namely, the granites. Again, in the north, the Whin Sill is more or less basic, or at least intermediate in character; it is perhaps significant, however, that the northern limit of the ores, in Northumberland, coincides nearly with the visible outcrop of the Whin Sill. Again, in Derbyshire, the veins are confined to the well-jointed limestones, and stop off short when they come up against the impervious rocks of the Yoredale facies. This is very noticeable in the small dome-like inlier of Ashover, where there are some very large fluorite veins. The general lie of the Derbyshire veins is just as

if the limestone had acted as a gasometer, confining the metal-bearing fluids, and depositing them in the open fissures, especially near its top. Now the structure of Derbyshire is clearly anticlinal, and the anticlinal arch must be supported by something. This structural consideration, taken in conjunction with the abundance of fluorine, suggest the possibility that far below there is a granite batholith, filling the core of the anticline (or anticlinorium).

In the far north, as pointed out by Mr. Carruthers, the relations appear at first sight to be very different. The productive parts of the veins mostly occur on the tops of hills, and in the valleys the veins are barren or nearly so. The rocks are horizontal or gently inclined (block structure), with a great fault on the west and a gentle tilt to the east. This is after all only a modification of an anticline. The explanation offered for this distribution of the ores really amounts to this ; that the ore-bearing solutions rose till they bumped up against the base of an impervious rock series, now removed by denudation, and were there checked, filling the upper parts of the fissures. We see, therefore, that this case, at first sight so unpromising, is by no means inconsistent with a direct magmatic origin for these ores. The existing descriptions of the famous old Ecton mine on the borders of Derbyshire and Staffordshire, afford a strong confirmation of the usual zonary sequences of ore in this area also : copper, zinc, lead, from below upwards. Again the lead-zinc-barytes deposits of Shropshire occur in an anticline, and the lead-ores of the Mendips, which were extensively worked at a very early date, are in a complex anticlinorial structure of the Armorican fold-system. The last-named instance is in a way specially instructive, because it is very difficult to see how such a structure could arise with an unsupported base. The cores of the overturned and overthrust anticlines must be filled by something, and this something it most easily conceived as magma. The Bath springs, issuing at 120° F., and strongly radioactive, are here highly suggestive of communication with a heated zone, by means of fissures extending down to great depths, and it is notable that these springs lie exactly on the prolongation of the N.–S. line of the Malvern Hills, a strongly disturbed and overthrust region. Again the copper-lead-zinc veins of the northern part of the English Lake District are obviously related to the Skiddaw granite, as it is hoped to show in a future paper. These deposits differ in many essential features from the lead-zinc veins of the northern Pennine area to the east of the Pennine fault.

It is of course perfectly true that there are innumerable areas where igneous rocks are abundant and ore-deposits scarce or non-existent, but this is only negative evidence, which is proverbially dangerous. Probably too much importance has been attached in this country to the scarcity of ores in the rocks of the Scottish Highlands. In Norway, where the Caledonides are also dominant, ores are common enough, and the British Isles are but a small area.

It is universally admitted that ores occur in great quantities within the region of the Armorican-Variscan trend-lines, but there is little of the sort to be seen in the highly disturbed region of western Belgium and northern France, which seems to be a comparable case.

Whatever may be said to the contrary by the opponents of magmatic ore-formation, the fact remains that in an immense number of cases ore-formation coincides with igneous activity, extrusive as well as intrusive, and that certain types of ore are associated with particular types of igneous activity: e.g., the tin-tungsten-molybdenum paragenesis with granite contacts and pneumatolysis; zinc, lead, and silver with plutonic rock-types accompanied by a lower grade of pneumatolytic activity; gold and silver tellurides, antimony and mercury with hydrothermal deposits belonging to the volcanic phase, and so on. This is a class of evidence which can scarcely be denied even by the most fanatical opponents of the theory.

It is impossible to help the feeling that in all the controversies on this subject too much importance has been attached to the study of cases of extremely doubtful interpretation, such as the sulphide masses and the Scandinavian iron ores, and too little to the innumerable instances where the genetic connection of ores and igneous rocks, both spatial and temporal, is perfectly clear and unmistakable. The sceptical attitude is always easier to maintain than that of a conclusive proof, and is usually more popular. And after all the opponents of magmatic ore-formation have usually little to offer of a positive character in support of their objections. They are generally ready enough to say where the mineralizing solutions did not come from, but they do not offer anything definite as an alternative.

It is only fair to say that Professor Gregory, in his latest book, *The Elements of Economic Geology*, p. 19, has made a suggestion which at any rate does offer a possible alternative, though in ultimate analysis it really resolves itself into much the same thing as a purely magmatic origin. As I understand this idea, which is very briefly expressed, it is that the metallic constituents of the mineralizing solutions are derived, not from the actual silicate magmas, but from the underlying (hypothetical) zone of mixed ores and silicates between the silicate crust and the nickel-iron barysphere, thus corresponding apparently to the oxide-sulphide zone of Goldschmidt. This of course is possible and plausible, but in the last resort this material must have been brought to the surface by the ordinary processes of magmatic injection and extrusion, so that it really differs but little from a purely magmatic origin in the broad sense, as previously defined. It is difficult to see how material from this zone could have been brought to accessible levels except by the intervention of eruptive processes of the ordinary type.

It will doubtless be noted that in all this discussion strong emphasis has been laid on the intervention of solutions in ore-

formation: in other words the chief part is attributed to water of magmatic origin. Opinions differ greatly as to the amount of water probably present in primary magmas: estimates appear to vary from 1 or 2 per cent to 20 per cent, but the lower figure appears the more probable. In any case even this must involve an enormous total volume. The real importance of this question lies in its relation to the probable viscosity of the ore-solutions. On the one hand, we have the conception of deposit from solutions, either dilutely molecular in the ordinary sense, or colloidal sols as postulated by Boydell, and on the other the intrusion of the viscous concentrated siliceous "vein-dikes" of Spurr. On this question, on the ground of physical chemistry, and in apparent agreement with Professor Waldemar Lindgren, I unhesitatingly come down on the side of solutions, either molecular or colloidal. The facts of ore-formation, so far as they are known to me, seem undoubtedly to indicate deposition from some form of dilute solution, with a small concentration of the ore-material as compared with the total volume. Mr. Spurr's vein dikes do not seem to leave any field for the phenomena of replacement, which have undoubtedly played an important part. And furthermore they are totally inconsistent with such types of ore-deposit as the great tin-lodes of Cornwall, for example, which are largely not fissure-fillings at all, but the alteration of great masses of rock, such alteration extending outwards for an indefinite distance from narrow cracks and along masses of shattered rock due to earth-movements (the so-called brecciated lodes). Neither can they account satisfactorily for the usual types of zinc-lead deposits in limestone, though something of the sort might conceivably have played a part in the formation of the veins with copper, zinc, lead, and barytes in the Lower Palaeozoic rocks of the British Isles.

Finally, as the last specific example, a very brief reference must be made to the close association of ores of many kinds with Tertiary volcanic activity of both extrusive and intrusive type, such as occurs so commonly in western America, and around the inner margin of the Carpathians. These ores mostly belong to the upper zones, as is natural, since denudation has not yet had time to reach and expose the lower zones, if such exist. In Bolivia it possibly has already done so.

In my book, *The Geology of the Metalliferous Deposits*, published in 1923, I gave on page 111 a scheme of classification of ores, in which under the heading of "Primary Deposits" the first category is defined as "Magmatic segregations within the boundaries of igneous rock-masses". The second category is defined as "Pegmatites and abyssal infillings and replacements from material extracted from magmas by differentiation: water of magmatic origin only", and the third as "Infillings and replacements at moderate depths with moderate temperatures and pressure: magmatic water or water heated by descent", while the last group includes ores due to meteoric water.

From the way in which this is expressed it might be taken to mean that only the first category is regarded as truly magmatic. This was not the intention at the time when it was written, and it is not my intention now. In order to make the matter quite clear, in any future re-publication of this classification I should qualify the first word, as for example by writing "intramagmatic" (though this is a barbarous hybrid) or some equivalent word. This would avoid the appearance of seeming to exclude the two following classes from the magmatic group. In the present state of our knowledge it is impossible to divide up the third class into those due to ascending and descending waters, if the last-named exist at all.

Thus I re-state my considered opinion that a very large number of vein-deposits and replacements are of magmatic origin, and that the term magmatic should be interpreted in the broad sense as set forth in this paper.

REVIEWS.

ISOSTASY. By WILLIAM BOWIE. pp. xiv + 275, figs. 39. E. P. Dutton and Co., New York. Price $2·00.

WHEN Professor J. F. Hayford retired from the United States Coast and Geodetic Survey, his mantle fell upon Dr. W. Bowie. The tests of the isostatic principle by means of the deflexions of the direction of gravity had already been very fully carried out. It remained for Dr. Bowie to investigate the anomalies of the intensity of gravity, which were found to give results in excellent agreement with those obtained from the deflexions. The work has been continued, with the object of examining the reality and the explanation of the anomalies still outstanding, mostly small, and the whole stands as the greatest piece of geodetic work ever carried out, and as one of our chief sources of information concerning the structure of the earth.

In Bowie's book the results are collected. The general result that inequalities of elevation over 100 to 200 metres in height appear to be compensated is thoroughly developed. Of the newer work, one may mention the discovery that the Mississippi delta is compensated, which indicates that compensation may keep pace with the accumulation of surface loads; also the association of negative anomalies with Cainozoic formations and of positive ones with the Pre-Cambrian and with anticlines.

Most of the geodetic information given in the book has already appeared in official publications of the Survey, but it is convenient to have it in a more concise form. A queer mixture of units is employed: vertical distances, for instance, are given in miles, kilometres, metres, and feet. The reader might have been spared

the trouble of carrying out so many conversions mentally. Also the author commits the elementary mistake of giving the values of gravity in dynes instead of in cm/sec^2 or in gals. A dyne is not a unit of acceleration, but of force.

The author is not content with displaying the evidence for isostasy as a fact of observation, but also discusses at length its physical interpretation and geological consequences. Here he conveys the impression that he is not sufficiently familiar with the literature of the subject. This is especially marked in his frequent references to Airy's theory of compensation. Airy's classical paper (*Phil. Trans.*, 1855) showed that if the earth's crust is supported on a denser fluid substratum, or even a weak solid one, mountains cannot be held up as mere added loads; they would inevitably break through the crust and become supported mainly by flotation on the substratum. It showed further that the result would be the marked reduction of the disturbance of gravity due to mountains that had already been discovered in India by Pratt. Pratt, in a later paper (*Phil. Trans.*, 1859), rejected Airy's explanation on three grounds. First, the greatest thickness of the crust considered by Airy was 100 miles, while Pratt accepted a result of Hopkins that it must be over 1,000 miles. The latter was based on one of those elusive arguments from the constant of precession that are answered in the modern theory of the figure of the earth. The second was that the crust would be denser than the substratum, not lighter, if it was formed by the solidification of the latter. The answer is that the crust is not merely in a different physical state, but made of specifically lighter materials. The third was that compensation of valleys, on Airy's theory, would imply an upward protuberance of the substratum into the lower surface of the crust, which could not be explained on any known theory of the cooling of the earth. It could, however, be explained easily as a result of faulting or bending due to the upward pressure of the substratum against the diminished weight of the denuded portion of the crust.

Bowie does not quote any of the above arguments of Pratt, and the reviewer finds it difficult to believe that he accepts any of them. On the other hand, he says (p. 19) that "the resisting upper rock may be likened to wood and ice resting on water". Here, and repeatedly elsewhere, he adopts Airy's fundamental postulate, which was denied by Pratt, that isostasy is to be attributed to the floating of a strong crust on a denser but weak substratum. There is, however, no indication in the book that a contribution of such importance is due to Airy.

Pratt's alternative hypothesis was that expansion or contraction of the crust due to cooling would, for mechanical reasons, take place mainly in a vertical direction, and would give inequalities compensated *ab initio*. The obvious objection to this theory is that it does not explain the compensation of inequalities produced by horizontal movement, such as folded mountains, denuded valleys

and deltas. For these Airy's mechanism is the only serious suggestion yet made, and probably nobody wants any other, seeing that it accounts automatically for the compensation of all inequalities however produced.

If a crust of uniform density floats on a uniform substratum of higher density, any vertical movement produced by the weight of surface inequalities will give compensation concentrated near the base of the crust. On the other hand, if the density in the crust increases uniformly with depth and becomes equal to that of the substratum at the base of the crust, a local vertical displacement will change the density at all depths in the crust by the same amount, and will give compensation uniformly distributed in depth. This was pointed out by the present reviewer (*Proc. Roy. Soc.*, 100, 1921, p. 131). Gravity observations alone cannot decide between these two types of compensation (*Gerlands Beiträge z. Geophysik*, 15, 1926, pp. 167–74). Bowie associates the former type with Airy's name, and uniform compensation with Pratt's, and expresses strong preferences for the latter. The reviewer cannot, however, follow his arguments, and can therefore only mention their existence. If the theory of a floating crust is once accepted, the vertical distribution of compensation depends on whether the variation of density with depth within the crust is steady or proceeds by sudden jumps. The study of near earthquakes has shown that three layers with different mechanical properties exist in the crust. If, as is probable, the transitions between them are rather abrupt, the compensation will be mainly concentrated at the two interfaces.

There is a remark on p. 224 that " Heiskanen has made gravity reductions by the Airy theory, but he has not expressed himself as favouring that one over the Pratt theory ". It is strange that this should be the only reference to Heiskanen's important work in a book dealing primarily with isostasy. It should at least have been said that Heiskanen found that the hypothesis of an upper layer of uniform density and variable depth gave, on the whole, slightly smaller residuals than that of uniform compensation. The unwary reader would infer from Bowie's reference that he had obtained the opposite result.

There is an extended discussion of the thermal contraction theory of mountain formation, which fails to touch any modern issue. Thus, on p. 204, we have: " Why should the temperature of the crust remain constant while the centre is cooling ? No convincing explanation of this phenomenon has been advanced so far as the writer is aware." The reviewer would refer him to the paper of 1921 just mentioned, p. 124, to *M.N.R.A.S.*, Apr., 1923, p. 351 ; or indeed to Kelvin. Bowie goes on: " The nucleus is supposed to contract and shrink away from the crust, leaving the crust detached with spaces between it and the nucleus. Then the crust collapses by the thrusting of the arch tangentially to the nucleus." The process would not take place in two stages as here asserted. Elastic

failure would occur when the stress-difference at some depth exceeded the strength there. The formation of cavities could occur only if the vertical pressure was reversed, and failure would occur at a much earlier stage. On p. 209 Bowie says that some students of the earth advance the idea that the earth is really getting hotter. "Among the most active advocates of this hypothesis are Harold Jeffreys, John Joly, and Arthur Holmes." Indeed!

Dr. Bowie's distinction as a geodesist will ensure that his book will be widely read, and attention to the parts that deal with his official work will be well bestowed. An extended notice has, however, been necessary to indicate that he is a dangerous guide outside his special sphere.

HAROLD JEFFREYS.

UPPER TRIASSIC MARINE INVERTEBRATE FAUNAS OF NORTH AMERICA. By J. PERRIN SMITH. pp. 1–262, pl. i–cxxi. U.S. Geol. Survey Professional Paper 141, 1927.

THIS paper is the third part of a complete revision of the North American Triassic marine invertebrate fauna. The upper Triassic fauna here described consists chiefly of Ammonoids (167 species), Pelecypods (52 species), and Corals (33 species); the upper Trias has been recognized in California (which possesses the best development known), Nevada, Oregon, British Columbia and Alaska. The localities are listed with their faunas (both from previous records and from original material), and the age of each suggested; four zones are recognized, a correlation table given, and the relations with the European time-scale indicated. The Mexican fauna described by Burckhardt is mentioned, but his identifications are not revised, since the material is considered "too poor for specific description".

The Jurassic rests unconformably on the Trias, there being no marine representative of the Rhaetic. The Noric is represented by two zones, the upper or *Pseudomonotis* zone, and the lower or Coral zone. The fauna of the former includes Pelecypods and Ammonoids, and affords evidence of a Boreal Province stretching over the whole area. The fauna of the Coral zone is characterized by the abundance of reef-forming *Astraeidae*, which by comparison with nearly related modern forms are thought to indicate a sea with a temperature not below 74° F. In this and the zone below (the upper Karnic or *Tropites subbulatus* zone the whole area seems to form one province; and the occurrence of the same or closely allied species leads to the conclusion that the Tethys stretched from India through the Mediterranean across the Atlantic to California and northward to Alaska. In the lower Karnic or *Halobia rugosa* zone, California belongs to the same Province; but the apparently contemporaneous beds in British Columbia and Alaska are characterized by a different fauna (the *Dawsonites* zone) indicating a Boreal Province.

Throughout the Karnic and lower Noric, 25 per cent of the fauna in California is identical with that of the Mediterranean, and a further 12 per cent closely allied.

The revision of the Ammonoids has led to the erection of many new genera and species; the classification is largely based on phylogeny, which in turn is based largely on the evidence of ontogeny.

A. G. B.

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(1) Cephalopods from the lower part of the Cody Shale of Oregon Basin, Wyoming. pp. 1–19, pl. i–viii. Prof. Paper 150—A.

(2) The Scaphites, an Upper Cretaceous Ammonite Group. pp. 21–40, pl. ix–xi. Prof. Paper 150—B.

(3) The Cephalopods of the Eagle Sandstone and Related Formations in the Western Interior of the United States. pp. 1–87, pl. i–xlv. Prof. Paper 151.

These three Professional Papers of the U.S. Geological Survey are by J. B. Reeside, jun.

(1) This horizon is correlated (chiefly by species of *Inoceramus* and *Scaphites*) with part of the Niobrara formation; the presence in the lower Cody shale of forms of *Inoceramus*, *Phlycticrioceras*, and *Mortoniceras* closely allied to European species, supports the customary correlation of the Niobrara formation with the European Coniacian (Emscherian).

(2) The Scaphites, from their wide distribution and relative abundance, are here considered an especially important group, useful even for intercontinental correlation. Previous attempts at classification are reviewed, and four genera (*Scaphites* Parkinson, *Desmoscaphites* Reeside, *Discoscaphites* Meek, and *Acanthoscaphites* Nowak) are recognized as valid; they are assigned to three families and four subfamilies. A very useful catalogue of all the species known to the author is given, with references.

(3) The first part of a work on the lower part of the Montana group (approximately Lower Campanian). The twelve genera here described include *Baculites*, *Scaphites*, *Placenticeras*, and two new genera.

A. G. B.

The Species Problem: An Introduction to the Study of Evolutionary Divergence in Natural Populations. By G. C. Robson. pp. viii + 283. Edinburgh: Oliver & Boyd, 1928. Price 15*s*. net.

As the sub-title indicates, this work is upon the problem of evolutionary divergence. The author states that he has used the expression "species problem" rather out of courtesy to a time-honoured convention than from the feeling that the early stages of divergence are best investigated as taxonomic species. The modern study of variation and race-formation in relation to environ-

ment is more likely to elucidate the causes of evolution than that of the fully separated species. The book appeals naturally more to the biologist than to the geologist, but there is an interesting account of the palæontological evidence bearing on the question of the correlation of variation found in certain groups of fossils which were apparently in process of transmutation. On this subject a statement of Trueman is quoted to the effect that in *Gryphaea incurva* of the Lower Lias the characters representing different lineages are "largely, if not wholly, independent of one another". The suggestion is made further that such a form may really have been an "impure" species composed of freely inter-breeding individuals whose pedigrees were interwoven. There is a chapter on "Isolation as a factor in the divergence of species" in which mention is made of Romanes' paper on "Physiological Selection" or sexual isolation. The author, however, omits to refer to the third volume of "Darwin and after Darwin", published after Romanes' death, in which that zoologist developed his conceptions further, expressing the view that Isolation along with Heredity and Variation is one of the three basal principles "on which is reared the whole superstructure of Organic Evolution". Romanes in that work affirms that Isolation is even more fundamental than Natural Selection as a factor in the origin of species, since Natural Selection is but a special form of Isolation, separating the "fit" from the "unfit". Full credit is given to Gulick by Romanes, the latter's conclusions regarding the influences of geographical isolation being admittedly based on Gulick's work. It is noteworthy, therefore, that Mr. Robson should have omitted to refer to Gulick's work published in the Linnean Society's *Journal* (vols. xx and xxiii) over thirty years ago. Regarding the three chief evolutionary hypotheses (Natural Selection, Mutation, and the Inheritance of acquired characters) the author is of opinion that we are still unable to assign their correct value to either of them for "until the cause or causes of variation . . . are known, and the means whereby variates are correlated are fully ascertained, we must remain in the realm of conjecture". Mr. Robson's work is critical and at the same time stimulating. It is a welcome addition to the series of "Biological Monographs and Manuals".

F. H. A. M.

REPORTS AND PROCEEDINGS.

Manchester Geological Association.

14th February, 1928.

"The Siluro-Devonian boundary in South Central Wales." By S. H. Straw, M.Sc., F.G.S.

The area under consideration forms a narrow strip of country extending from the Wye Valley, south-east of Builth, along the scarp

of Mynydd Eppynt and south-westwards to Llanfiangel Aberbythych, south-west of Llandeilo. Over most of this tract the rocks dip steeply in a south-easterly direction. They have been studied in a number of excellent sections at Cwm Craig Ddu, Cwm Dwr, the River Sawdde, etc., as well as along the outcrop in the intervening regions.

Evidence is brought forward to show :—

(1) That the *Grammysia*-Trichrûg beds of the southern part of the area belong to the zone of *M. leintwardinensis*, and cannot, therefore, mark the base of the Devonian, as suggested by Stamp in 1923.

(2) That the Tilestones are of Downtonian age and are closely allied stratigraphically to the overlying Old Red Marls.

(3) That the Upper Ludlow which is several hundred feet thick in the Wye Valley thins out south-westwards under the Tilestones, which thenceforward rest unconformably on beds of the *leintwardinensis* zone. This unconformity is the north-eastward continuation of the one below the Old Red Sandstone (Green Beds) of South Caemarthenshire.

The Siluro-Devonian boundary in South Central Wales is, therefore, drawn at the base of the Tilestones.

The Green Beds may represent (in part, at least) a lateral passage of the Tilestones, but it is considered more probable that they overlap them, since they appear to be of slightly later date, judging from the presence in them of *Lingula cornea*, which occurs also in the Old Red Marls above the Tilestones in the Sawdde section, but has not been identified from the Tilestones. A similar overlap is believed to occur in the Builth district. Near Cwm Craig Ddu the Tilestones disappear and the Upper Ludlow is succeeded by greenish quartzite overlain by green and red marls.

Geologists' Association.

2nd March, 1928.

The following lecture was given: "River Meanders," by Professor E. J. Garwood, M.A., Sc.D., F.R.S., F.G.S.

"The Geology of the Country between Rhayader and Abergwesyn." By K. A. Davies.

The southern portion of the Central Wales Plateau forms the north-western limb of the Towy Anticlinorium, the axis of which runs from Central Radnor to Carmarthenshire.

This limb has many subsidiary folds parallel to the main axis, and these, with change of pitch brought about by cross-folding, bring up inliers of older rocks. The sediments themselves are all of Upper Ordovician and Lower Silurian age, but whilst the former comprise the rocks on the immediate flanks of the axis, only in

one inlier do Ordovician strata appear. This occurs between Rhayader and Abergwesyn on the Breconshire-Radnorshire border.

The Ordovician rocks of this area are mainly composed of shales, mudstones, grits, and conglomerates, and contain much the same graptolite species as found elsewhere. The country is chiefly remarkable for the fact that conglomerates occur throughout the succession, but the unconformity and overlap within the Lower Silurian, or Birkhill, observed at Rhayader are not present in this adjoining area.

Glasgow Geological Society.

8th March, 1928.

"The Carboniferous Rocks of the Coalburn District of Lanarkshire." By George Ross, B.Sc.

The district is bounded on the west by the River Nethan, and comprises an area of 18 square miles. The structure of the district is discussed and the detailed stratigraphy described from sketch-maps and sections. Local variations are described and correlations and comparisons are made with the Central Coalfield and the Glenbuck District. The formations represented are : (1) The Calciferous Sandstone Series, (2) The Lower Limestone Group, (3) The Limestone Coal Group, and (4) The Upper Limestone Group and the Millstone Grit. The Calciferous Sandstone comprises (1) a Lower Division of grits and red and yellow sandstones, conformable with the Upper Old Red ; (2) a middle Division of marls and thin limestones, and (3) an Upper Division of Scottish Carboniferous Limestone facies, with fossiliferous limestones, faikes, blaes, etc.

The zonal value of the following fossiliferous horizons is emphasized: *Productus giganteus* Limestone, Main Limestone (*P. giganteus* mut. showing absence of furrowing in the umbonal region), *Posidonomya corrugata*, Johnstone shell-bed, and Index Limestone. In the Upper Limestone Group the Orchard, Calmy, and Castlecary Limestones have been identified in bores.

"The Igneous Geology of Central Ayrshire." By V. A. Eyles, B.Sc., J. B. Simpson, B.Sc., and A. G. Macgregor, M.C., B.Sc.

This preliminary account summarizes previous research and presents new information concerning the post-Silurian igneous rocks, gained during a re-examination of the Ayrshire Coalfield by the Geological Survey.

Lower Old Red Sandstone.—The lavas (andesites and olivine-basalts) occupy stratigraphically the topmost position of this formation. Volcanic necks of this age are definitely recorded for the first time in Central Ayrshire. The following types occur as sills or dykes ; felsite, porphyrite, plagiophyre, basalt, dolerite, and quartz-dolerite. There is a dioritic intrusive complex locally very

rich in tourmaline; it has baked the country rocks, into which tourmaline has been intruded pneumatolytically. One lava analysis is given.

Calciferous Sandstone.—The exact relationship of the Heads of Ayr neck and the bedded ash of Greenan Castle are discussed, and reference is made to a basalt lava which has undergone lateritic weathering, resulting in the formation of bauxitic clay.

Millstone Grit.—The occurrence and distribution of olivine-basalt lavas of this age in the Ayr Coalfield are discussed. The lavas have been subjected to lateritic weathering, but no economically important deposits of iron-ore or bauxitic clay have been found associated with them. Three clay analyses are given.

Permian (*New Red Sandstone*).—The age relationships of the lavas (basic alkali-basalts, with analcite- and nepheline-basalts), the numerous volcanic necks, the smaller intrusions (monchiquite and analcite-basalts), and the larger sills are all discussed in detail. The sills include such types as sub-alkaline olivine-dolerite, alkali-dolerite, teschenite, nepheline-teschenite, camptonite, theralite, kylite, picrite, and peridotite, as well as decomposed olivine-dolerite with juvenile quartz. Analyses of two lavas and one sill are given.

Tertiary.—The majority of the dykes of the district are classed as tholeiites or as olivine-dolerites of crinanite type, and are considered to be Tertiary. A few of the olivine-dolerite sills are regarded as of this age.

"The Classification of Scottish Carboniferous Olivine-Basalts and Mugearites." By A. G. MacGregor, M.C., B.Sc.

This paper discusses the progress of research on the Scottish Carboniferous olivine-basalts and mugearites (lavas and intrusions) since 1892, the date of Dr. F. H. Hatch's paper on the Lower Carboniferous volcanic rocks of East Lothian. The macroporphyritic olivine-basalts (Markle, Dunsapie, and Craiglockhart types), the microporphyritic olivine-basalts (Jedburgh, Dalmeny, and Hillhouse types) and mugearites are re-defined so as to combine the minor modifications proposed by successive workers. A precise definition of the current terms "macroporphyritic" and "microporphyritic" as applied to Scottish Carboniferous olivine-basalts by the officers of the Geological Survey of Scotland is given, and the diagnostic field characters of the various types are discussed. Reasons are given for discontinuing the use of the old terms "Kilsyth type", "Lion's Haunch type", "Gallaston type", "Picrite type" and "Kippie Law type". An annotated table of all published analyses of Scottish Carboniferous olivine-basalts and mugearites is incorporated.